

Historic, Archive Document

Do not assume content reflects current scientific knowledge, policies, or practices.

28B991
I2I5
Reserve

U.S. DEPARTMENT OF AGRICULTURE
SEA-AR/BLM COOPERATIVE STUDIES

REYNOLDS CREEK WATERSHED

Northwest Watershed Research Center
Western Region
Agricultural Research
Science and Education Administration
U. S. Department of Agriculture

INTERIM REPORT NO. 10

Cooperative Agreement No. 12-14-5001-6028

For Period January 1, 1979 to December 31, 1979

TO

Denver Service Center
Bureau of Land Management
U. S. Department of Interior
Denver, Colorado

FEBRUARY 1980

UNPUBLISHED AND PRELIMINARY INFORMATION: Contents of this report are for administrative purposes only and may not be published or reproduced in any form without prior consent of the research worker or workers involved.

TABLE OF CONTENTS

	<u>Page Number</u>
INTRODUCTION	1
STAFF	4
ANNUAL WORK PLAN FOR FY 1979	5
PROGRESS REPORTS	7
1. PRECIPITATION	8
a. Reynolds Creek	9
b. Boise Front	26
2. VEGETATION	28
a. Reynolds Creek	29
b. Boise Front	47
3. RUNOFF	53
a. Reynolds Creek	54
b. Boise Front	80
4. EROSION AND SEDIMENT	82
a. Reynolds Creek	83
b. Boise Front	105
5. WATER QUALITY	106
a. Reynolds Creek	107
b. Boise Front	112
6. RAINFALL SIMULATION	118
ACHIEVEMENTS	120

NOTE: Generally, a variety of watershed data are compiled on a calendar year basis. However, the water year, beginning October 1 and ending September 30, has proven best for hydrologic comparisons.

INTRODUCTION

Cooperative watershed research between the Science and Education Administration-Agricultural Research, U. S. Department of Agriculture, and the Bureau of Land Management, U. S. Department of Interior, was initiated in 1968 under Cooperative Agreement No. 14-11-0001-4162(N). Also, the Memorandum of Understanding, dated July 6, 1960, which is a part of the Cooperative Agreement, specifies the overall responsibility of each agency.

This interim report summarizes progress and results on the Reynolds Creek Watershed and supporting studies on the Boise Front from October 1 through September 30, 1979. Data collection, processing, analyses, and reporting are according to the FY 1979 work plan. Progress reports are given by the individual sections of the work plan. A copy of the FY 1979 work plan precedes the progress reports.

Supporting information and data are presented in Northwest Watershed Research Center Annual Reports for 1972 and prior years and in Interim Reports No. 1, 2, 3, 4, 5, 6, 7, 8, and 9 for the AR-BLM studies in the Reynolds Creek Watershed under Cooperative Agreement No. 12-14-5001-6028.

Progress this year was highlighted by a number of opportunities to report completed and ongoing analyses to BLM and SCS groups. This interaction with potential users of research results insures that ongoing or proposed research will be relevant to action agency research needs.

Collection of late cover at eight vegetation sites at Reynolds Creek was made possible by the field leadership from M. P. MacFarlane, BLM State Office.

The retirement of "Bud" Cox and Gilbert "Gil" Schumaker, and transfer of John Zuzel in FY 1979 have severely curtailed our research in the Snow, Vegetation, and Water Quality modeling. At least one hydrology position and possibly another will be filled in FY 1980. However, SEA-AR research capability in the Vegetation area will remain as a real void.

We acknowledge the unique and significant inputs that Gil, Bud, and John have made to the SEA-AR research program and to our interagency cooperative research.

Introduction Figures 1 and 2 locate major experimental sites on Reynolds Creek (Figure 1) and the Boise Front (Figure 2).

Additional copies of this report or further information on reported work can be obtained from:

Northwest Watershed Research Center
USDA, SEA-Agricultural Research
1175 South Orchard, Suite 116
Boise, Idaho 83705

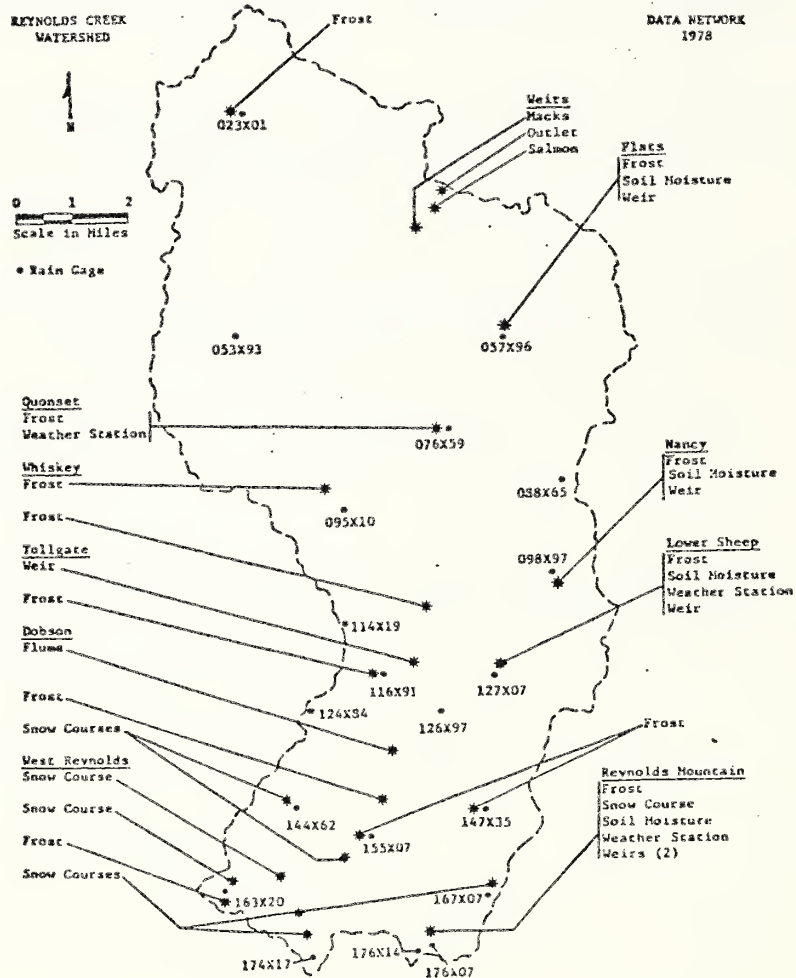


Figure 1.--Reynolds Creek Watershed

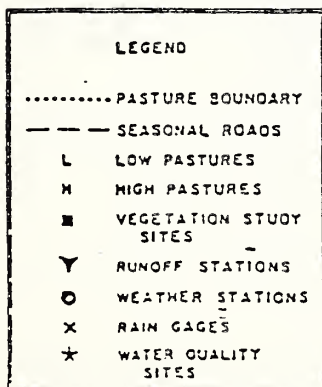
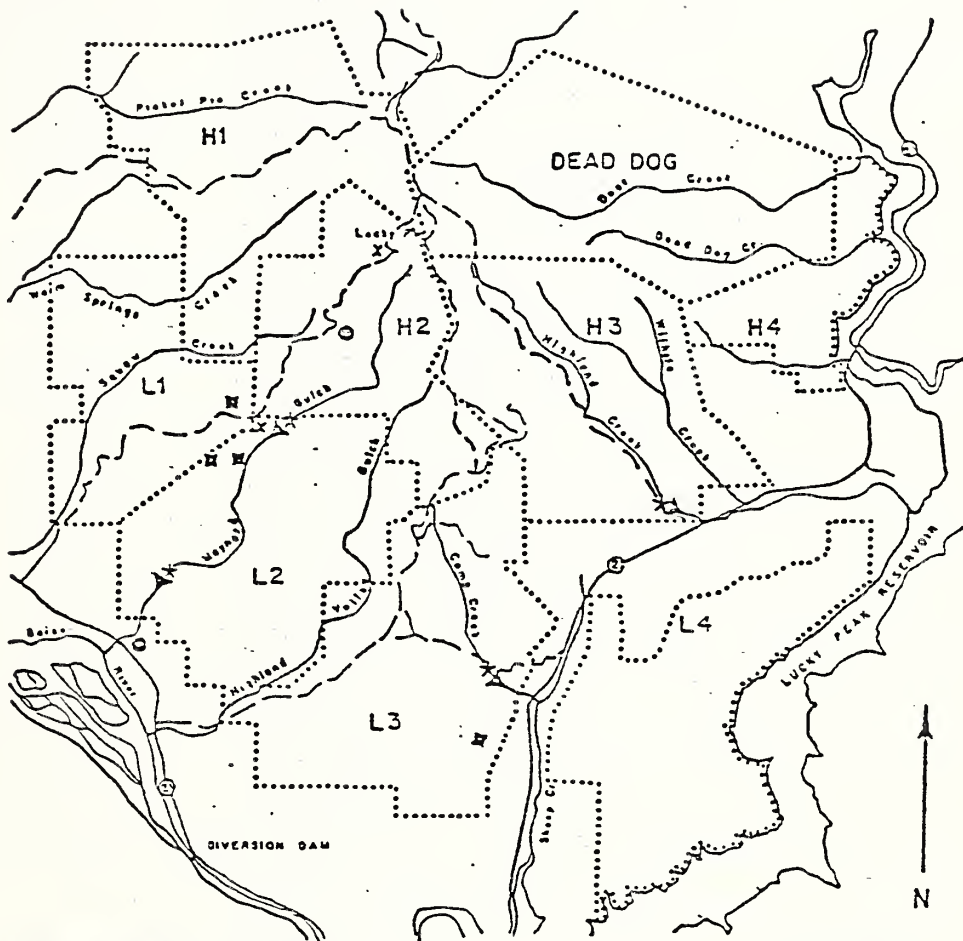


Figure 2.--Boise Front

STAFF

<u>NAME</u>	<u>TITLE</u>	<u>SERVICE DATES*</u>
Aaron, Virginia M.	Hydrologic Technician	
Brakensiek, Donald L.	Research Hydraulic Engineer (LL & RL)	
Burgess, Michael D.	Electronic Technician	
Butler, Donna M.	Administrative Officer	
Campbell, Michael D.	Hydrologic Aid (Perm., 32 Hr/Wk)	1/15/79-Present
Coon, Delbert L.	Hydrologic Technician	
Cox, Lloyd M.	Hydrologist	Retired 8/31/79
Critchlow, Diane M.	Clerk-Typist (Perm., 32 Hr/Wk)	11/18/79-Present
Engleman, Roger L.	Mathematician	
Hanson, Clayton L.	Agricultural Engineer	
Harris, James H.	University of Idaho Cooperator- Scientific Aid III	
Harris, Shari K.	CETA Employee - Clerk-Typist	1/21/79-7/23/79
Hennefer, Shari L.	Clerk-Typist (Perm., 32 Hr/Wk)	11/4/79-Present
Hoagland, Jerry	University of Idaho - Irregular Employee	11/4/79-Present
Hoagland, Roy M.	Automotive Mechanic	
Hornbaker, Sonny	Boise State University Cooperator - Technician	12/14/78-5/10/79
Johnson, Clifton W.	Research Hydraulic Engineer	
Kleiner, Karl W.	Range Aid (Temp., 180-day Appt.)	4/8/79-8/31/79
Kroeger, Shirley C.	University of Idaho Cooperator - Research Technician	4/15/79-Present
Morris, Ronald P.	Hydrologic Technician	
O'Brien, Rebecca L.	Hydrologic Aid (Temp., 180-day Appt.)	11/18/79-Present
Perkins, Lee	Machinist	
Robertson, David C.	Hydrologic Technician	
Schumaker, Gilbert A.	Soil Scientist	Retired 8/31/79
Schumaker, Vera H.	Clerk-Stenographer (Perm., 35 Hr/Wk)	8/27/78-10/27/79
Smith, Jeffrey P.	Hydrologic Technician	
Stephenson, Gordon R.	Geologist	
Stillings-Jackson, Sue	Boise State University Cooperator - Technician	9/18/77-8/9/79
Thomson, Michael S.	University of Idaho Cooperator - Technical Aid	3/16/75-3/2/79
Trautman, Kenneth W.	Engineering Equipment Operator	
Wallof, Nancy	Boise State University Cooperator - Technician	4/19/79-8/24/79
Wilson, Glenna A.	Purchasing Agent	
Zuzel, John F.	Hydrologist	Transferred 9/8/79

* If other than whole year.

BLM-SEA ANNUAL WORK PLAN FOR FY 1979

INTRODUCTION: The following activities are necessary to meet the objectives stated in Paragraph III of Bureau of Land Management Interagency Agreement No. YA-515-IA8-21, dated September 19, 1978. Certain elements in this plan of work indicate continuation of work from previous years. In many cases, this continuation of inventory is required to sample climatic variability and to evaluate the cumulative effects of grazing practices on hydrologic processes and watershed, soil, water, and vegetal factors. SEA research on Reynolds Creek and the Boise Front will supplement many of the items contained in this work plan.

1. PRECIPITATION

Develop and display via maps or tabulations, (12 sets) modeling of Reynolds Creek Watershed monthly and annual precipitation amounts. Initiate preparation of similar material for comparable areas of Idaho, Oregon, and Nevada. Commence development of a daily amounts stochastic precipitation model from Reynolds Creek data. A summary of Reynolds precipitation data will be reported in an SEA publication. Precipitation network operation will be continued on Reynolds and at satellite watersheds.

2. VEGETATION

Complete and report on development and application of a climate-forage yield model, to include sensitivity analyses and model verification. Continue annual vegetative surveys on the Boise Front, which will consist of species composition, cover seedling density and kind, and establishment. Determine late cover at eight SEA vegetation sites at Reynolds Creek. Data are to be reported in the 1979 FY Annual Report.

3. RUNOFF

Perform a probability analyses of Reynolds Creek Watershed runoff amounts at six runoff stations. Continue evaluation of the SCS runoff equation for watersheds at Reynolds Creek and at two runoff stations on the Boise Front rest-rotation system.

4. EROSION AND SEDIMENT

Determine USLE soil loss and PSIAC sediment yields for selected range sites on Reynolds Creek. Report cover and soil loss values in FY 1979 annual report. Continue sediment sampling at four sites on Reynolds Creek and two sites on the Boise Front.

5. WATER QUALITY

Complete report on the calibration of a water quality model (DO, BOD, Total Biomass) for Reynolds Creek. Complete a SEA report on water quality data for Reynolds Creek. Continue water quality sampling on the Boise Front rest-rotation system.

6. RAINFALL SIMULATION

The experimental design will be formulated and field sites selected for FY 1980 field tests. The soil, vegetal, and other plot descriptors to be used during FY 1980 will be selected and measurement procedures developed for their use. Physical requirements and logistics and planning actual rainfall simulator test procedures will be evaluated and developed.

PROGRESS REPORTS

1. PRECIPITATION

Personnel Involved

C. L. Hanson,
Agricultural Engineer

Supervises the planning and design of precipitation studies; performs analyses and summarizes results.

V. M. Aaron,
Hydrologic Technician

Responsible for data reduction and processing.

D. L. Coon and R. P. Morris,
Hydrologic Technicians

Responsible for data collection, compilation, and assist with analyses.

R. L. Engleman,
Mathematician

Responsible for data compilation and assists in analyses.

M. D. Campbell,
Hydrologic Aid

Assists in data reduction and processing.

a. Reynolds Creek

(Reynolds Creek Experimental Watershed locations are shown in Introduction, Figure 1.)

PRECIPITATION ANALYSIS

The 17-year (1962-1978) precipitation record from the Reynolds Creek Experimental Watershed was used in several studies during the past year. These studies were done as part of the hydrologic modeling program at the Northwest Watershed Research Center and the results are also being incorporated into the precipitation models being developed under the BLM research program. Summaries of these studies follow.

Annual and Monthly Precipitation: The average annual precipitation on the Reynolds Creek Experimental Watershed ranged from about 250 mm on the low elevation (1100 m) in the northeastern area, to about 1100 mm at the high elevation (2150 m) in the southwest area of the watershed (Figure 1.a.1). These precipitation differences were associated with elevation and storm patterns, which move onto the watershed from the west and southwest. This storm pattern caused high precipitation amounts on the south and west sections of the watershed and precipitation shadows on the north and northeast sections.

Precipitation on the watershed increased with elevation and showed a seasonal pattern, with lowest amounts in July and greatest amounts in December and January (Table 1.a.1). The location of the four sites listed in Table 1.a.1. is shown in Figure 1.a.1. The data in Table 1.a.1. show that 41 percent of the average annual precipitation fell from May through October at the low elevation, 1194 m, station 076X59; whereas, only 24 percent fell during the same period at the high elevation, 2166 m, station 163X20. These percentage differences show that a greater proportion of the annual precipitation fell during the winter at high elevations than at the low elevations. This can be attributed to the way the winter storms move over the watershed from the west and southwest.

Monthly and annual precipitation at the four sites, (Table 1.a.1.) show how precipitation varied by month with elevation. July had the least average precipitation at the four sites, and ranged from 7 mm at 076X59 to 16 mm at 155X07 and 163X20. The greatest average monthly precipitation was during January, and varied from 39 mm at 076X59 to 208 mm at 163X20. In general, July, August, and September were the driest months and November, December, and January were the wettest.

June precipitation was greater than May or July precipitation at the four sites. This June maximum at Reynolds Creek Station 076X59 does not show up in the 38-year (1940-1977) record at the Boise Airport, where the average monthly precipitation for each month, February to

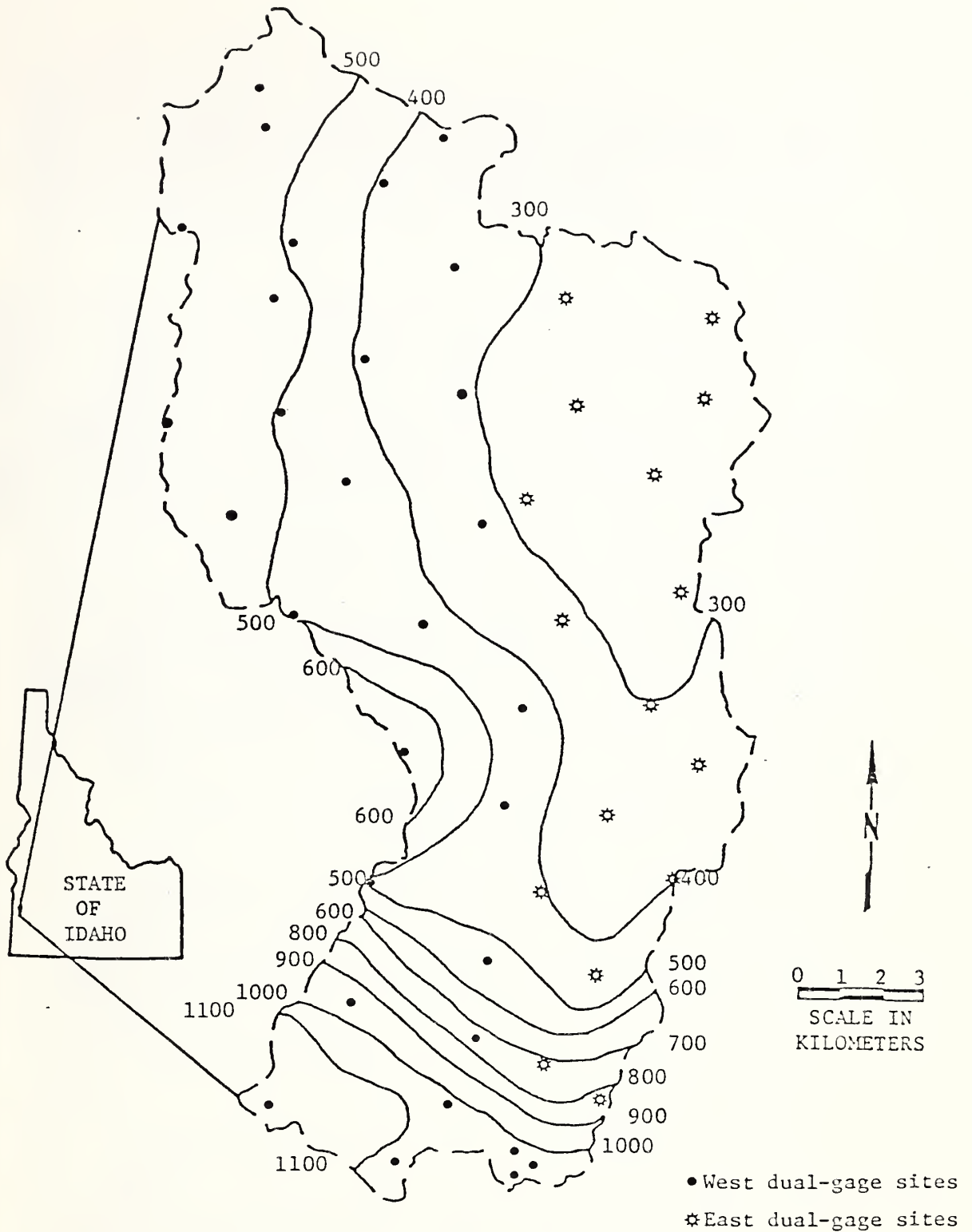


Figure 1.a.1.--Isohyetal map with the locations of the precipitation measuring sites, Reynolds Creek Experimental Watershed. Numbers indicate millimeters of annual precipitation.

Table 1.a.1.--Monthly and annual precipitation (mm) at 4 sites on the Reynolds Creek Experimental Watershed, 1962-1977.

	Site							
	076X59 (1193 m)		116X91 (1454 m)		155X07 (1649 m)		163X20 (2164 m)	
	Millimeters		Millimeters		Millimeters		Millimeters	
	Average	High Low	Average	High Low	Average	High Low	Average	High Low
January	39	106 9	71	160 18	120	268 27	208	417 69
February	19	43 6	37	66 10	66	125 17	111	254 30
March	23	65 2	44	105 3	73	157 17	118	273 23
April	22	80 3	44	99 10	58	118 8	92	178 19
May	19	44 3	30	63 6	43	86 10	60	162 20
June	37	77 7	43	106 12	50	110 11	62	117 8
July	7	26 0	10	29 0	16	47 0	16	52 0
August	18	101 0	17	77 0	26	106 0	28	142 0
September	12	40 0	19	58 0	25	71 0	31	81 0
October	23	73 5	39	130 9	53	181 11	67	182 24
November	31	60 4	54	101 2	92	179 6	148	302 20
December	33	132 2	63	219 4	102	311 6	166	378 17
TOTAL	283	372 ^{1/} 175 ^{2/}	470	624 ^{1/} 320 ^{2/}	724	1044 ^{1/} 493 ^{2/}	1107	1472 ^{1/} 828 ^{2/}
Summer total	116		157		213		264	
Winter total	167		313		511		843	

^{1/} Greatest calendar year precipitation of record.

^{2/} Least calendar year precipitation of record.

June, ranged from 26 mm to 30 mm and then decreased to 5 mm in July (Figure 1.a.2). The 16-year (1962-1977) record at Boise also indicates that during that period, May precipitation was below average and June precipitation was above average. The low monthly precipitation (Table 1.a.1) varied from none at least one year during July, August, and September at all sites to high amounts more than five times the monthly mean during August at site 076X59.

The yearly maximum precipitation varied from 1.31 times the average at 076X59 to 1.44 times the average at 155X07. The year with the least precipitation ranged from 0.62 times the average at 076X59 to 0.75 times the average at 163X20, which shows that there was less yearly variation at the high elevations during this period of record.

Annual and Monthly Precipitation-elevation relationships: Precipitation-elevation relationships are shown in Table 1.a.2. The regression equations were computed for all stations (Figure 1.a.1), as well as on a west-and-east side stratification. The equations were based on the mean precipitation for 38 stations with the longest records. The information in Table 1.a.2 shows that the precipitation-elevation relationship depends on season and site location. Precipitation increased less with elevation increase during the summer months than the winter months. This shows that, on the average, summer precipitation is more uniform over the watershed than winter precipitation. Generally, more precipitation fell at the higher elevations than at the low elevations from the winter frontal storms.

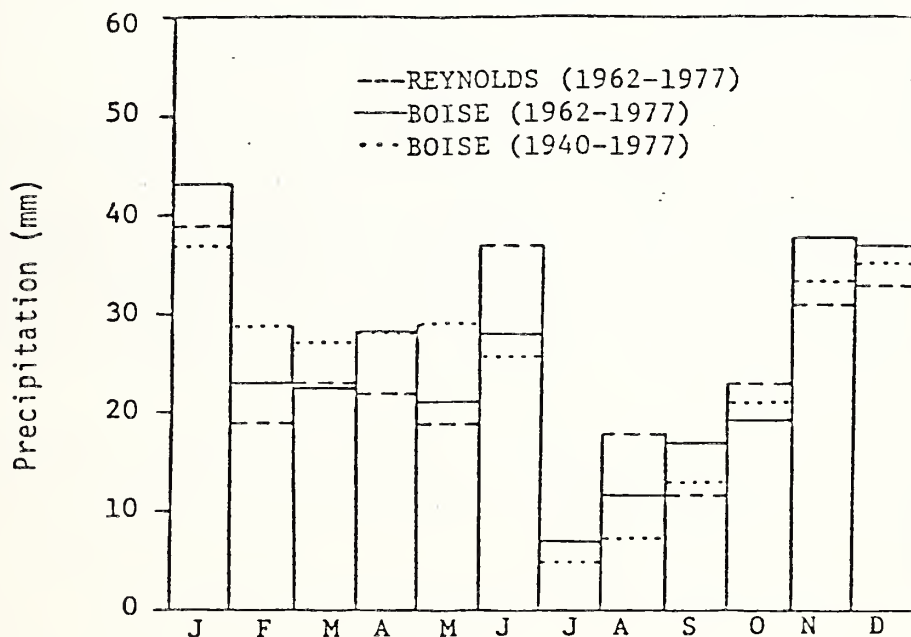


Figure 1.a.2.--Monthly precipitation at Reynolds Creek Watershed, site 076X59 and the Boise WSO AP station, Idaho. Average annual precipitation: 283 mm, Reynolds (1962-77); 296 mm, Boise (1962-77); and 295 mm, Boise (1940-77).

Table 1.a.2--Regression equation $Y = a+bX$ relating precipitation (Y) in mm to elevation (X) in m.

		Regression Coefficients		R^2 ^{1/}	SE	N
		a	b			
All Stations	Annual	-513	0.647	0.640	140	38
	November-April	-476	0.520	0.621	117	38
	May-October	- 36	0.127	0.672	26	38
East Side Stations	Annual	-203	0.372	0.585	101	14
	November-April	-219	0.294	0.549	86	14
	May-October	15	0.078	0.680	17	14
West Side Stations	Annual	-652	0.772	0.806	105	24
	November-April	-598	0.625	0.778	92	24
	May-October	- 54	0.147	0.863	16	24

^{1/} R^2 = Coefficient of determination
SE = Standard error
N = Sample size

In general, the east side of the watershed received less precipitation than the west side. This was because the greatest precipitation-producing storms moved over the watershed from the southwest to northwest, and the highest mountains on the watershed are along the south and southwest side of the watershed. The precipitation-elevation relationships for the west side of the watershed were higher than the east side, as indicated by the coefficient of determination (R^2). This would indicate that the mean precipitation is not as uniformly distributed on the east side as on the west.

This does not indicate the effect of summer thunderstorms, which, in many cases, were very local and did not cover large areas. This local thunderstorm phenomenon is especially prevalent at the lower elevations at the north end of the watershed.

CHARACTERISTICS OF REYNOLDS CREEK STORMS

Storm duration: Many hydrologic and engineering investigations require a knowledge of precipitation characteristics, such as storm duration and time between storms. Sites 076X59 and 163X20 were selected for these investigations, because they are located in the low and high elevation precipitation regimes.

The number of storms during the December-January and July-August 2-month period were considered indicators of the precipitation regimes at both sites. There were 104 storms during July and August for the 16 years at 076X59, and 139 at 163X20, which correspond with the greater average July and August precipitation at 163X20 (Table 1.a.3). Precipitation per storm averaged 4 mm at 076X59 and 5 mm at 163X20. At 076X59, there were 14 storms with durations of 15 minutes or less and 45 storms that lasted less than 1 hour. There were more storms in these two categories at 163X20, but they accounted for approximately the same percentage of the total number of storms. One storm at 076X59 and four storms at 163X20 lasted more than 1 day. The longest storm at 163X20 was 43 hours.

As can be seen from Figure 1.a.3, the July-August cumulative frequency curves for both sites are the same for storms of 5 hours duration and greater. These storms account for approximately 20 percent of the storms. These analyses show that the summer storm durations were similar at the two sites.

During December and January, there were 328 and 499 storms at 076X59 and 163X20, respectively. Precipitation per storm averaged 4 mm at 076X59 and 12 mm at 163X20 during this period. Precipitation per storm was approximately the same at site 076X59 for both the summer and winter conditions. At site 163X20, however, the winter storms had more than three times the precipitation per storm than during the summer.

Approximately 50 percent of the storm durations at the high elevation site, 163X20, were 1 hour or less during July-August and 5 hours or less in December-January. Similarly, 50 percent of the storm durations at the elevation site 076X59 were also 1 hour or less in July-August, but only about 3 hours or less in December-January, showing that summer storms were of approximately equal duration at high and low elevations, but that winter storms had much longer durations at the high elevations than at the low elevations.

During December and January, 7 percent of the storm durations were shorter than 1 hour at 163X20 and 16 percent at 076X59, another indication that winter storms had longer durations at 163X20 than at 076X59. At 076X59 there were five storms that lasted more than 24 hours, and the longest storm lasted 41 hours. At 163X20 there were 31 storms that lasted more than 24 hours; three that lasted more than 48 hours, one of which lasted 83 hours. As shown in Figure 1.a.3, at 076X59, 50 percent of the storms were less than 3 hours in duration; whereas, 50 percent of the storms at 163X20 were less than 5 hours in duration.

Interval Between Storms: The interval between storms for sites 076X59 and 163X20 is shown on Figure 1.a.4. As with storm durations, the July-August interval between storms was about the same at both sites. Data in Table 1.a.4 shows that 50 percent of the intervals were about 1.7 days or less. The maximum interval between summer storms was 57 days at 076X59 and 63 days at 163X20. At both sites, approximately 40 percent of the intervals were 1 day or less, which indicated that during the summer some days experienced more than one storm.

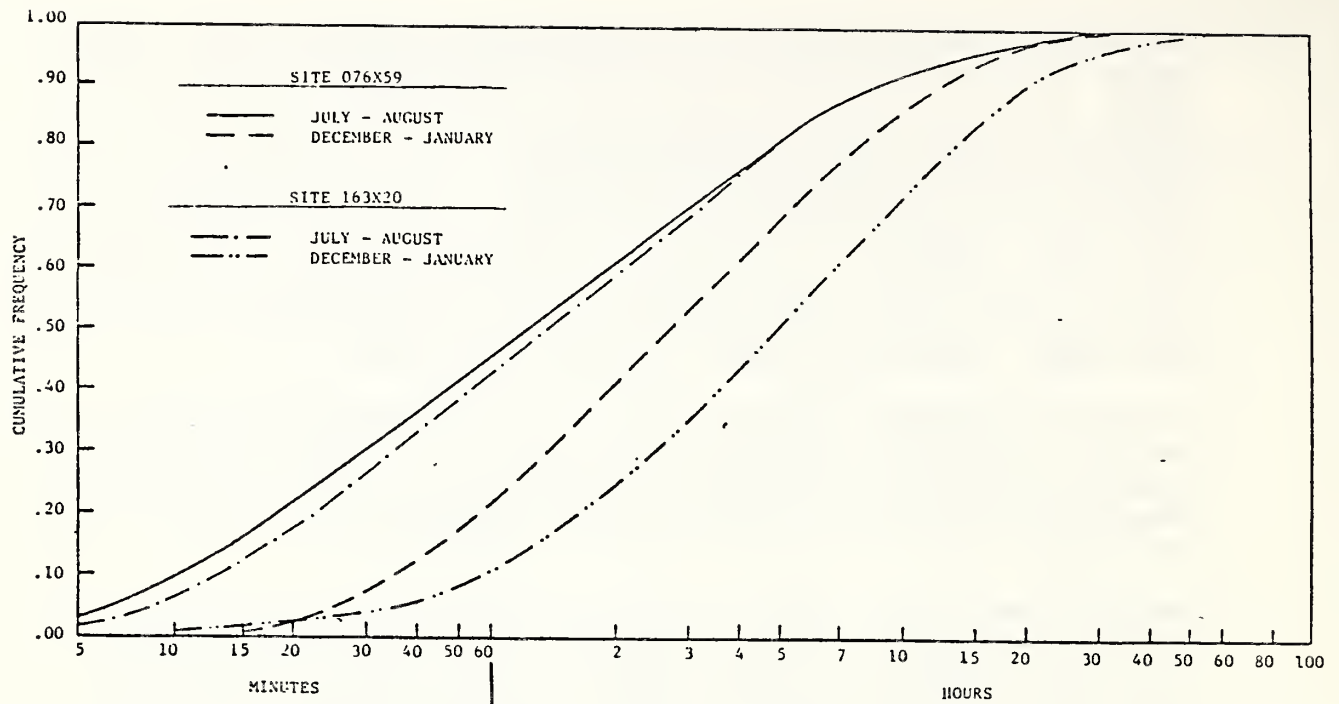


Figure 1.a.3.--Duration of storms during July-August and December-January at sites 076X59 and 163X20.

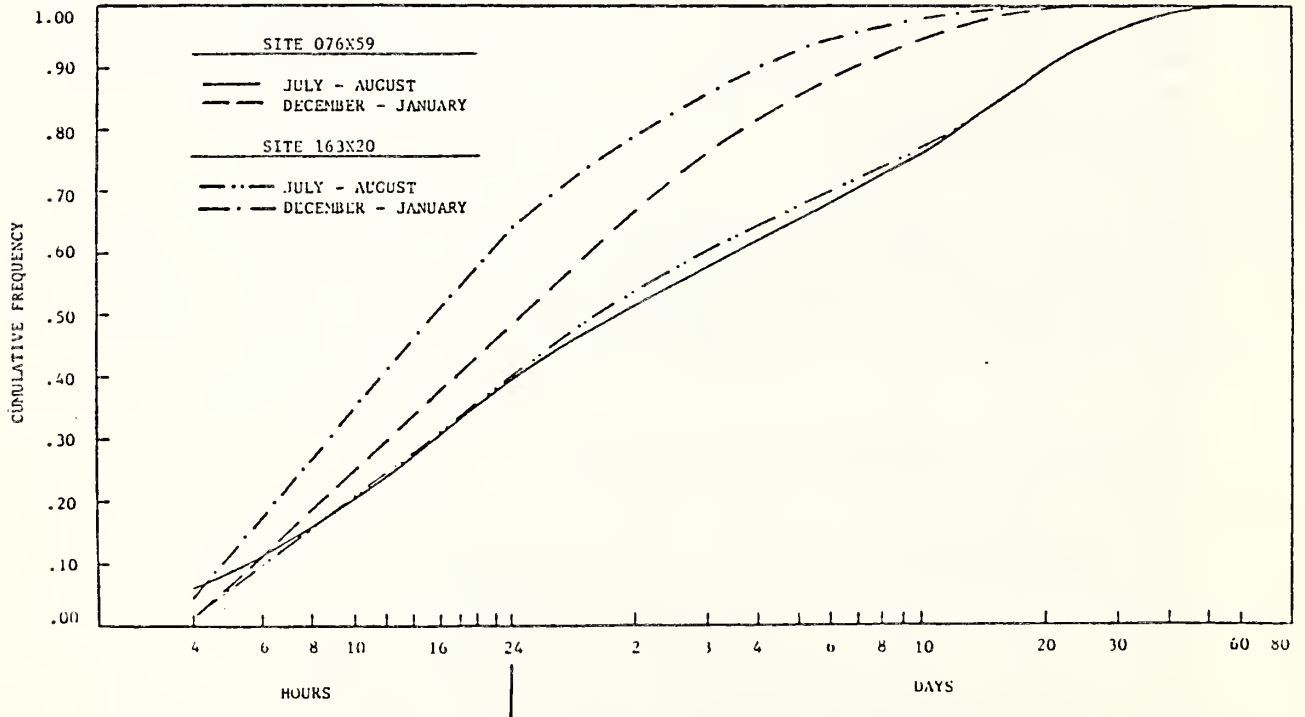


Figure 1.a.4.--Interval between storms during July-August and December-January at sites 076X59 and 163X20.

Table 1.a.3.--Frequency of storm durations.

Time		Precipitation Site			
		December	- January	July	- August
Hours	Min.	076X59	163X20	076X59	163X20
	5	0	1	3	3
	10	0	3	3	6
	15	3	3	8	9
	20	7	5	11	9
	30	12	7	12	12
	40	16	11	4	8
	50	15	5	3	6
1	00	32	30	8	9
1	30	31	34	7	10
2	00	20	25	6	9
2	30	13	24	5	8
3	00	22	28	3	6
3	30		21	2	5
4	00	30	27	5	5
5	00	22	29	2	9
6	00	20	28	5	5
7	00	14	22	2	2
8	00	13	22	5	4
9	00	5	15	2	2
10	00	4	21	0	2
11-20		39	92	7	6
21-30		9	28	1	2
31-40		0	10	0	1
41<		1	8	0	1
Total Storms		328	499	104	139
Mean		5.2 Hours	8.6 Hours	3.4 Hours	3.9 Hours
Median		3.0 Hours	5.0 Hours	1.0 Hours	1.5 Hours

As would be expected, the time between storms during the winter was less than during the summer. The cumulative frequency curves for the two sites were very different during the winter months, which reflects different conditions than those occurring during the summer months when the two curves were almost the same. At 076X59, 50 percent of the intervals were 1 day or less; and at 163X20, 50 percent were 15 hours or less. These data show that at both sites there are many days when more than one storm occurred during the same day. The longest period between winter storms was 42 days at 076X59 and 24 days at 163X20. The data indicate that most of the dry intervals were 20 days or less at 076X59 and 17 days or less at 163X20.

Table 1.a.4.--Frequency of intervals between storms.

Time		Precipitation Site			
		December - January		July - August	
Hours	Days	076X59	163X20	076X59	163X20
4-8		73	143	15	23
9-13		31	73	12	12
14-18		22	49	5	7
19-24		38	63	14	17
	1.5	29	38	3	12
	2	31	38	5	9
	3	24	31	8	3
	4	22	19	2	8
	5	11	9	1	2
	6	9	13	4	5
	7	5	5	5	3
	8	4	3	3	1
	9	5	2	2	2
	10	2	3	2	5
	11-15	17	6	6	7
	16-20	2	3	6	12
	21<	3	1	11	11
Total Intervals		328	499	104	139
Mean . . . Days		2.9	1.7	7.7	6.6
Median . . . Days		1.0	0.7	2.0	1.5

Two-year, 6-hour precipitation: The Universal Soil Loss Equation (USLE) is being adapted to western U. S. rangeland conditions. One of the parameters in the USLE is the 2-year 6-hour precipitation in inches. For most erosion studies, the 2-year 6-hour precipitation values are obtained from the precipitation frequency atlas of the Western United States (Hershfield, 1961). The following analyses were done to determine how well the figures in the atlas represented the precipitation frequency conditions found on Reynolds Creek Experimental Watershed.

Partial duration frequencies for the 21 sites with 15- or 16-year records were determined from annual series data according to the procedures outlined in the atlases (Miller, Frederick, and Tracey, 1973; Hershfield, 1961) and (Haan, 1977). The values obtained from the analyses were plotted on the isopluvial map (Figure 1.a.5). As can be seen, the 2-year 6-hour values are about 20 mm at the lower elevation areas on the north and eastern sides of the watershed. The values generally increase with increasing elevation, with the maximum value of 40 mm at the 2000 m elevation on the south and west sides of the watershed. The relationship between the 2-year 6-hour values and elevation is shown in Figure 1.a.6. The regression relationship between the 2-year 6-hour values and elevation is

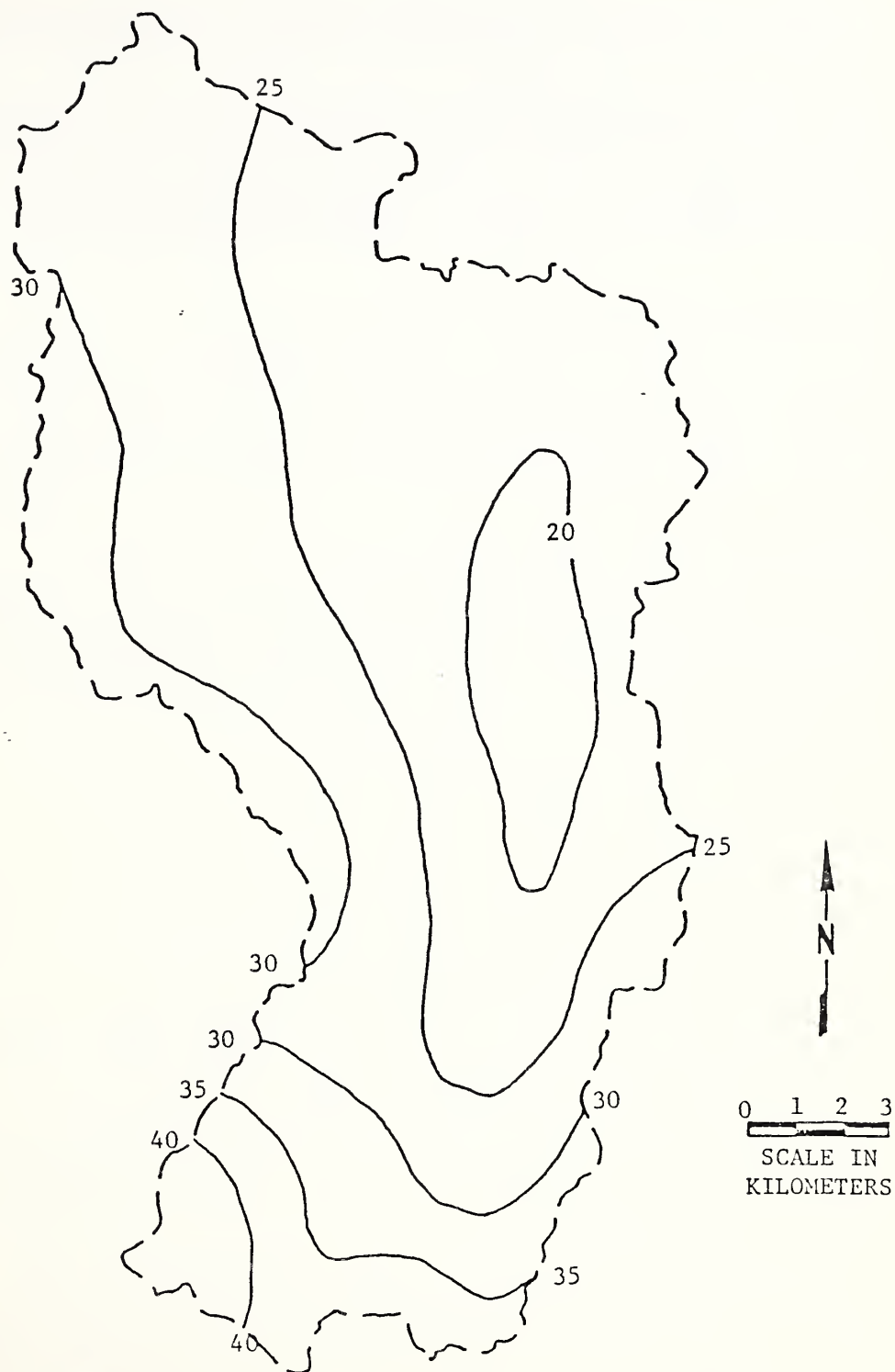


Figure 1.a.5.-- Isopluvials of 2-year 6-hour precipitation, in millimeters, Reynolds Creek Experimental Watershed.

$$Y = 0.04 + 0.01X$$

$$(R^2 = 0.69)$$
(1)

where, \bar{Y} is the 2-year 6-hour precipitation in mm and X is the elevation expressed in meters. As mentioned before, the direction of storm travel, source of water, and location of the mountains affected the precipitation distribution on the watershed. This can be seen in this analysis, because the higher precipitation values were located on the southwest section, and the lower values were located on the north and east sections of the watershed in the rain shadow. One of the reasons for the variability in the data was that there was more precipitation on the southwest side than on the east side of the watershed at the same elevations.

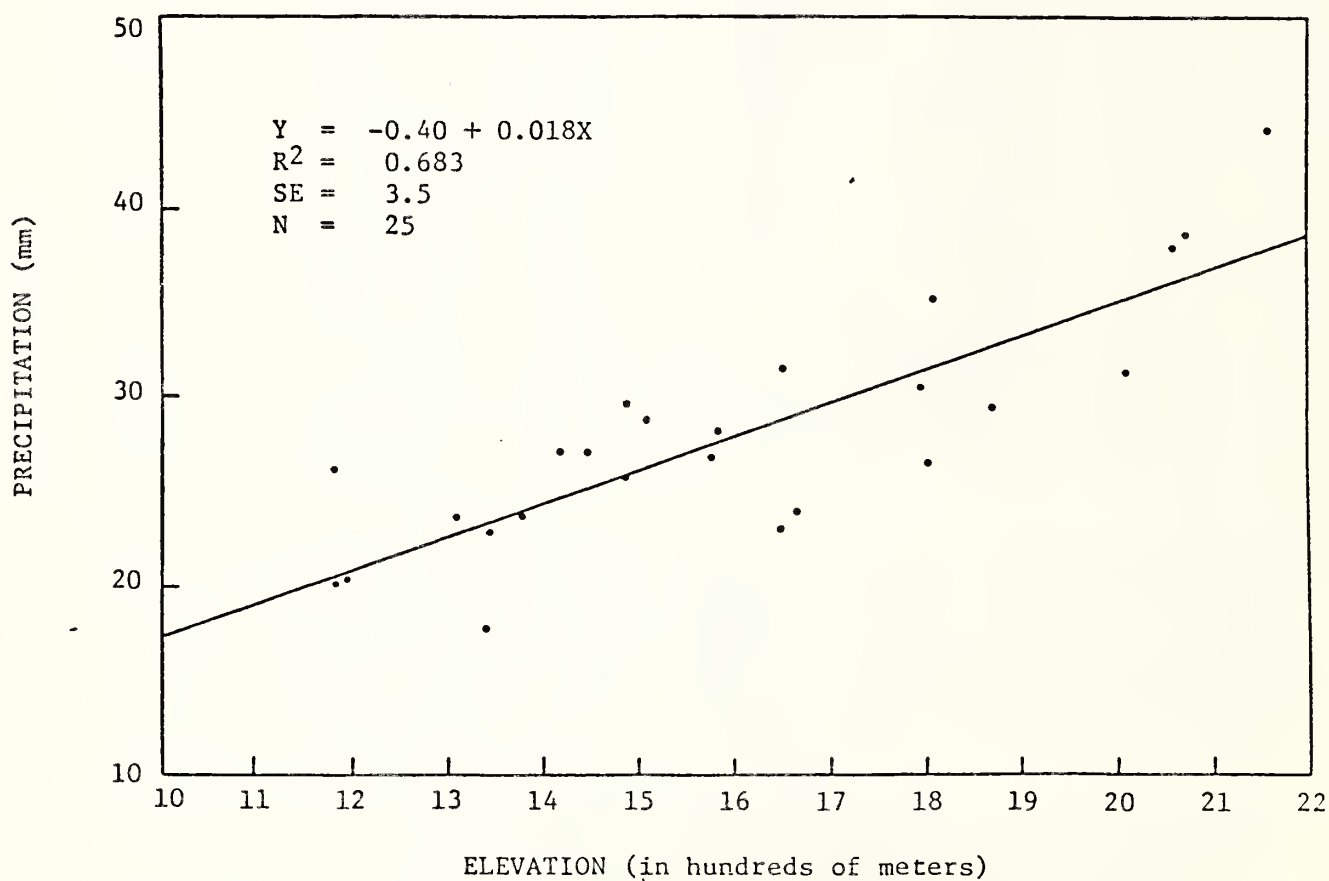


Figure 1.a.6.--Relationship between 2-year 6-hour precipitation and elevation.

The maximum annual 6-hour precipitation amount occurred during the summer in six of the 16 years at 076X59 and in only two of the 16 years at 163X20. This indicates that the summer thunderstorms contribute a significant number of the maximum precipitation events at the lower elevation; whereas,

at the higher elevation, winter storms generally are the cause of the greatest 6-hour precipitation. The precipitation frequency atlas shows a 2-year 6-hour frequency value of 20 mm for the watershed area. This is a good estimate at the lower elevations, but does not represent the elevations above about 1600 m. As shown on Figure 1.a.5, the atlas should contain frequency values of 40 mm or more at the higher elevations of this mountain range, if the USLE is to be accurately used.

Precipitation-Frequencies: Seven precipitation sites with 17-year (1962-78) records were used to develop a method of estimating precipitation amounts for any return period up to 100 years at different elevations on Reynolds Creek Experimental Watershed. Data from these seven sites were used in this study, because the annual precipitation at these sites represents the driest to the wettest conditions on the Watershed (Figure 1.a.1).

The summer (May through October), winter (November through April), and annual maximum (5, 15, 30 minute; 1, 2, 4, 6, 12, and 24-hour) precipitation amounts were tabulated for each site. These values were then fitted to the Fisher-Tippet Type I distribution by the method of moments. This was the same distribution used by the National Weather Service in the precipitation frequency atlas of the Western United States (Hershfield, 1961).

The computer program used to fit the Fisher-Tippett distribution generated the 2, 5, 10, 20, 50, and 100-year precipitation amounts for each time period. A sample of the generated values is shown on Figure 1.a.7. Because these generated values plotted as straight lines on log-log paper, the coefficients of the following equation were fitted for each site:

$$Y = aX^b \quad (2)$$

where,

Y = precipitation amount (mm)

X = precipitation duration (hours)

a&b = coefficients.

Figure 1.a.8 was drawn for summer, winter, and annual precipitation so that when elevation and return period are known, the maximum precipitation amount for any storm duration can be estimated. Two examples of the procedure follow:

1. The 20-year, 10-hour maximum annual precipitation is needed for a site at 1500 m. The values for "a" and "b" from Figure 1.a.8 were:

$$a = 22$$

$$b = .405$$

$$Y = 22(10)^{.405} = 55.9 \text{ mm.}$$

2. The 50-year, 6-hour maximum winter precipitation is needed for a site at 2000 m. The values for "a" and "b" from Figure 1.a.8 were:

$$a = 21.5$$

$$b = .62$$

$$Y = 21.5(6)^{.62} = 65 \text{ mm.}$$

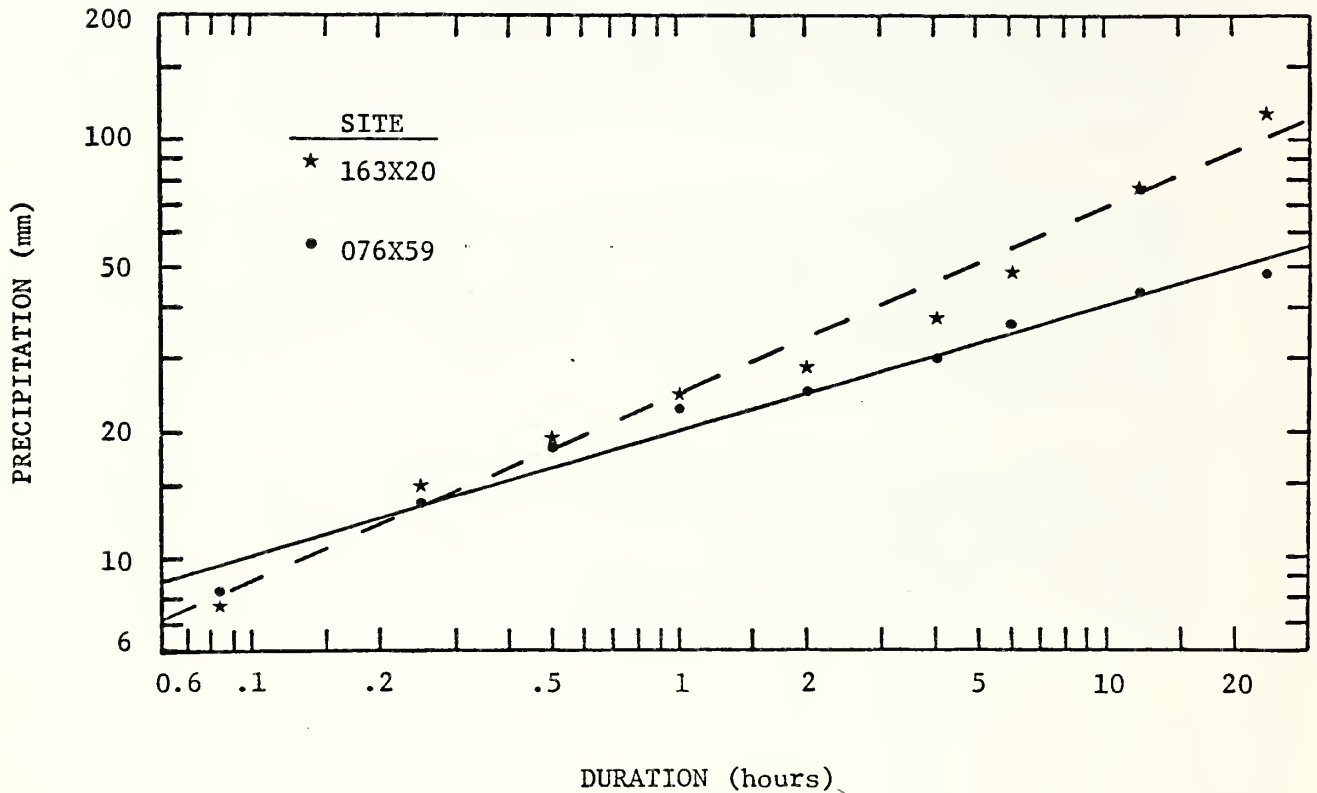


Figure 1.a.7.--10-year return period for annual maximum precipitation.

The iso-coefficient lines on Figure 1.a.8 show that maximum winter precipitation increases with elevation. This is not the case for summer precipitation amounts, which are highest at low and high elevations and least at mid elevations. This is because there are more intense thunderstorms at the low elevations and greater amounts of precipitation at the high elevations. This summer storm regime carries over into the annual values, so the shorter duration maximum amounts are during the summer at the low elevations and almost all maximum amounts are during the winter at the highest elevations. This analysis indicates that caution has to be taken when these type of data are being used to design engineering structures, etc.

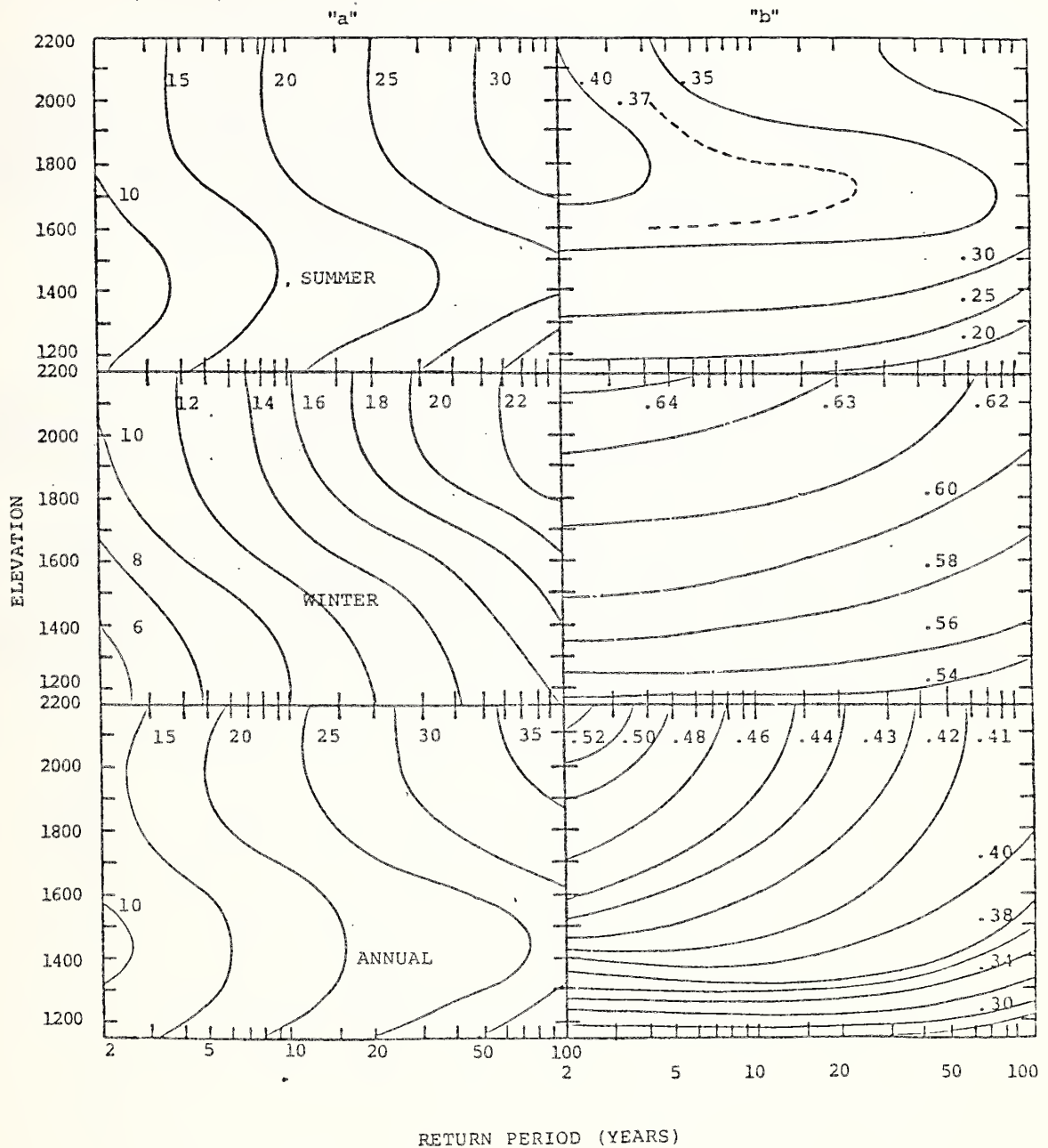


Figure 1.a.8.--Iso-coefficients for computing summer, winter, and annual precipitation amounts.

Reynolds Creek

1979 Precipitation

(Reynolds Creek site locations on Introduction Figure 1).

The four precipitation sites listed in Table 1.a.5 represent the precipitation conditions that existed on the watershed. The annual precipitation was below average at all sites and precipitation varied from 3.1 inches below average at 076X59 to 9.3 inches below average at 176X07. The winter (November through April) precipitation and summer precipitation (May through October) were both about 25 percent below average.

WYOMING SHIELD GAGE STUDY

The evaluation of the Wyoming shield was continued at site 127X07, (Introduction Figure 1). The new sites were established, one at a high elevation location, 167X07, and the other at 076X59, a low precipitation site, to determine if the catch relationship between the dual-gage system and the Wyoming shield system is the same at all elevations.

Analysis of 52 rain and/or snow events at site 127X07 showed that the dual-gage and the Wyoming shield systems measured the same amount of precipitation when a value of 1.7 was used for the coefficient "B" in the dual-gage equation (Hanson, Morris, and Coon, 1979). The data from the three sites will be evaluated to determine if "B" in the dual-gage equation varies with elevation.

Table 1.a.5.--Water year precipitation (inches) at four locations on Reynolds Creek Watershed.^{1/}

Site	Elevation	Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Total
076X59	3965	1979	0.010	1.056	0.415	1.300	0.640	0.560	0.740	0.650	0.300	0.090	2.180	0.060	8.001
		1963-1979	0.859	1.227	1.231	1.537	0.773	0.912	0.947	0.678	1.386	0.291	0.816	0.481	11.138
116X91	4760	1979	0.060	2.325	1.119	2.350	1.609	0.959	1.422	1.540	0.918	0.169	2.030	0.010	14.511
		1963-1979	1.445	2.159	2.419	2.699	1.417	1.684	1.780	1.129	1.636	0.427	0.772	0.711	18.278
155X07	5410	1979	0.070	2.395	1.862	3.294	3.713	1.438	2.247	2.252	0.469	0.100	2.139	0.180	20.159
		1963-1979	1.964	3.564	3.873	4.707	2.671	2.737	2.406	1.640	1.891	0.614	1.140	0.940	28.147
176X07	6760	1979	0.100	3.593	3.060	6.439	6.326	2.473	3.551	2.896	0.576	0.250	3.078	0.040	32.382
		1963-1979	2.216	5.561	6.116	8.211	4.474	4.150	3.653	2.250	2.249	0.574	1.214	1.040	41.708

^{1/} Rain gage locations are shown on Introduction, Figure 1.

REFERENCES: SECTION 2.a

Haan, Charles T. 1977. Statistical methods in hydrology. The Iowa State University Press, Ames. 378 pp.

Hershfield, David M. 1961. Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years. U. S. Department of Commerce, U. S. Weather Bureau Technical Paper 40. 115 pp.

Miller, J. F., R. H. Frederick, and R. J. Tracey. 1973. Precipitation-frequency atlas of the Western United States. Volume V-Idaho. U. S. Department of Commerce, NOAA Atlas 2. 43 pp.

b. Boise Front

(Boise Front Site Locations are shown in Introduction, Figure 2.)

The 1979 water year precipitation for the four sites on the Boise Front and the Boise Airport are listed in Table 1.b.1. The 1977-1979 average amounts at the four sites on the Boise Front and 39-year average at the Boise Airport are also listed in the Table. As can be seen, 1979 precipitation was below the 1977-1979 average at all sites. At the Boise Airport, annual precipitation was 12 percent below average, and winter (November-April) precipitation was 8 percent below average. These data show that the precipitation on the Reynolds Creek Watershed and the Boise Front was below average and that the Reynolds Creek Watershed was drier than the Boise Front.

Table 1.b.1.--Water year precipitation (inches) at four locations on the Boise Front, and the Boise Airport.

Site	Elevation	Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Total
328X86- ^{1/}	2880	1979	0	1.110	.860	2.296	1.499	.590	1.550	1.460	.229	0	1.148	.198	10.940
		1977-1979 ^{2/}	.110	1.610	1.873	2.210	1.883	.931	1.656	1.323	1.294	.356	.776	1.033	15.055
322X62	3800	1979	.010	1.353	1.258	2.532	2.177	.821	1.979	1.739	.403	0	1.309	.170	13.751
		1977-1979	.357	1.296	1.673	2.126	2.344	1.530	2.160	1.636	1.444	.387	.738	1.165	16.856
314X50	4650	1979	.030	1.837	1.515	3.925	3.101	1.233	2.200	1.907	.300	0	1.812	.220	18.080
		1977-1979	.366	1.804	2.169	3.114	2.738	2.044	2.303	1.861	1.584	.563	1.023	1.311	20.880
311X94	5450	1979	.050	1.922	2.020	3.463	3.531	1.460	2.603	2.329	.250	0	1.813	.212	19.153
		1977-1979	.471	1.814	2.472	2.466	3.115	2.255	2.999	2.134	1.367	.537	1.061	1.419	22.110
Boise	2838	1979	0	1.060	.600	1.930	1.200	.480	1.600	1.280	.180	.010	1.810	.040	10.190
Airport		1941-1979	.830	1.320	1.360	1.480	1.140	1.050	1.140	1.170	1.020	.210	.350	.530	11.600

^{1/} Gage installed February 1977.

^{2/} Monthly averages for October through February are for 1978 and 1979 only.

2. VEGETATION

Personnel Involved

G. A. Schumaker,
Soil Scientist
(Retired August 31, 1979)

Plan, design, and supervise field studies and coordinate research activities and prepare reports.

C. L. Hanson,
Agricultural Engineer

Perform computer analyses relative to field studies and assist in planning field studies.

D. L. Coon,
Hydrologic Technician

Assist in data collection and noting field observations, including soil moisture measurement and calibration.

J. P. Smith,
Hydrologic Technician

Assist in vegetation data reduction.

K. W. Kleiner,
Range Aid (Temporary)

Assist in vegetation data collection and reduction.

a. Reynolds Creek

(Reynolds Creek site locations are shown on Introduction, Figure 1).

Herbage yield: Grazed and ungrazed herbage yields were obtained during 1979 in support of the forage yield modeling study at the nine sites shown on Figure 2.a.1. Site descriptive information is given in Table 2.a.1. Table 2.a.2 is a summary of the total herbage yield and herbage yield with the shrub species yields removed.

Herbage yield was sampled at each site when the major grass species had headed. The nonwoody portion of the shrubs was considered annual growth and was the only portion sampled. Annual herbage production was determined by the double-sampling method, where two people estimated each of the 10 randomly selected 9.6 ft² samples in each treatment. Three samples per treatment were clipped and weighed. All sample weights were adjusted to an air-dry weight of 12 percent moisture. Small exclosures were used to protect sampling areas within the grazed treatment from livestock. Grazing of the area surrounding the fenced exclosures was not controlled except at Nettletons, where the heavy grazing treatment was imposed in a fenced area.

There were only three mean yields that were significantly different. The total yield of the grazed treatment at the Flats was significantly greater and the ungrazed treatment nonshrub yields were significantly greater at Lower Sheep and Nettletons.

The mean total herbage yield of the grazed treatment was greater than the ungrazed treatment at six of the nine sites; however, as mentioned previously, only the mean difference at the Flats was significant, because the year-to-year yield variations were large, mean differences had to be large before significant differences could be obtained.

The mean nonshrub herbage yields were greater on the ungrazed plots than on the grazed areas at six of the nine sites. These data would indicate that the shrub herbage yields were as high or higher on the grazed areas. After nine years of study, there was no noticeable trend developing toward greater or lesser yields in the exclosures (ungrazed) or on the grazed areas.

At the Upper Sheep Creek and Reynolds Mountain dense sites, there was a large shrub yield decrease from 1977 through 1979. This change was due to the winter kill of Mountain Big Sagebrush (*Artemisia tridentata vaseyana*) during the low snow cover winter of 1976-77. As can be seen from Table 2.a.2, a considerable amount of the sagebrush was also killed out on the Reynolds Mountain sparse site, but the snow cover at this site is normally about the height of the sagebrush and the kill was not extensive. At the Upper Sheep and the Reynolds Mountain dense sites, the snow cover is generally several feet deep, because they are snow deposition areas.

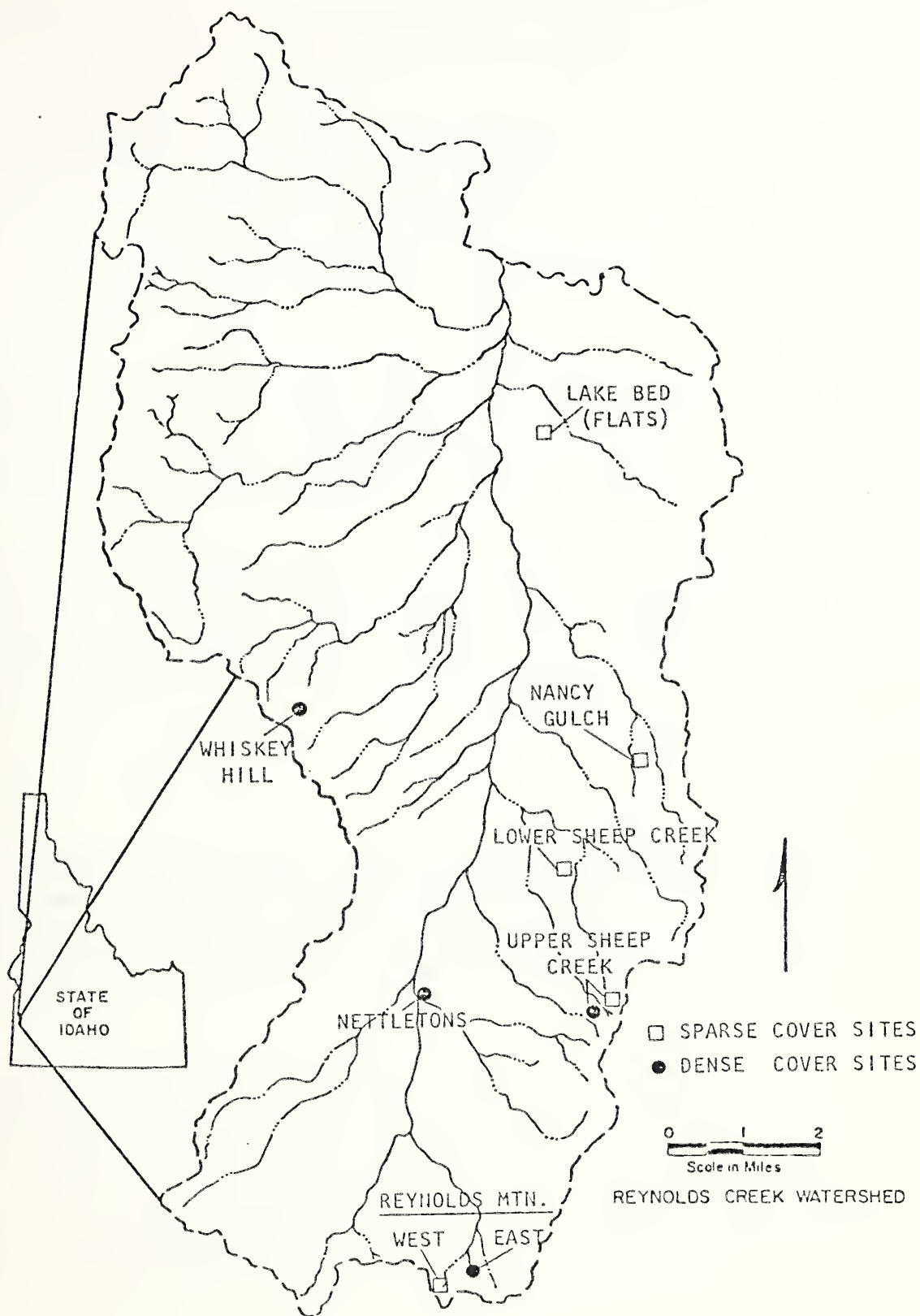


Figure 2.a.1.--Location of study sites.

Table 2.a.1.--Site information

Site	Elevation feet	Slope %	Aspect of Slope	Precip. inches	Vege- tative Cover %	SCS Hydro. Class.	Effective Precip. Period
Flats	4000	5	N	10	25	B	November-April
Whiskey Hill	5500	15	E	20	50	B	November-March April-May
Nancy Gulch	4600	8	NE	12	25	C	November-April
Lower Sheep Creek	5400	16	NW	14	25	B	November-May
Nettleton	4900	38	W	19	25	D	November-May
Upper Sheep Creek (sparse)	6100	33	SW	15 ^{1/}	25	D	November-March April-May
Upper Sheep Creek (dense)	6100	33	NE	15 ^{2/}	50	C	November-March April-May
Reynolds Mountain (sparse)	6850	5	SW	41 ^{1/}	25	B	November-April May-June
Reynolds Mountain (dense)	6800	6	NW	41 ^{2/}	50	B	November-April May-June

^{1/} Snow removed by wind^{2/} Snow deposition zone

Climate-herbage yield model: Sneva and Hyder (1962a, 1962b) developed a procedure for estimating herbage yield that was based on an effective precipitation time period. Their procedure requires an estimate of the median herbage yield and median effective precipitation at a site, and is expressed in the following form:

$$Y = 1.11X - 10.6 \quad (1)$$

where, Y is the yield index (%) and X is the precipitation index (%). Equation (1) can be used to estimate herbage yield by having an estimate of the precipitation as a percent of the median precipitation and calculating the herbage index. The herbage index is then multiplied by the median herbage yield to obtain the yield for the year in question. This procedure can, thus, be used to compute an average yield and the range of expected yields at a location from precipitation records. Herbage yield estimate can also be made for any year based on the precipitation that has fallen prior to harvest.

The basic structure of equation (1) was selected as the basic model for our studies, because only one equation would have to be used to estimate yield on Reynolds Creek Watershed by knowing which precipitation period represented the yield at a site.

Model development and testing: Median herbage yields for each study site were computed from the data in Table 2.a.2. Median herbage yields by study site were computed by averaging either the middle four or five values in the yield array. Four values were averaged when there was an 8-year record and five were averaged when there was a 9-year record. The median precipitation for several time period combinations for each study site was also computed, using the same procedure as discussed for herbage yield.

The herbage yield index at each site was an average of the grazed and ungrazed yield, except at the Flats. At the Flats the grazed and ungrazed average yields were significantly different and, thus, they were analyzed separately (Table 2.a.2). Regression analyses were used to obtain the best fit equation between the yearly yield index values and the associated precipitation index at each study site.

The initial regression analysis showed that the effective precipitation period varied, as shown in Table 2.a.1, at the sites below 5500 feet in elevation. The analysis for sites at 5500 feet and higher showed that there was little or no correlation between a single effective precipitation period and herbage yield. The data from the four lower elevation sites were then combined and the following equation was developed for them:

$$Y_L = 1.39X_L - 0.27 \quad (2)$$

where, Y_L is the yield index (%) and X_L is the precipitation index (%) for the four lower elevation sites. The slope of equation (2) was not significantly different from equation (1); however, the intercept was significantly different, which indicated that the two equations were not interchangeable. These analyses would suggest that equation (2) should be used for forage estimation for areas represented by Reynolds Creek Watershed and lower than 5500 feet.

A review of the data indicated that two precipitation periods were required to represent sites at 5500 feet and higher. The preliminary data analysis also suggested that each precipitation period contributed about 50 percent of the total yield. Precipitation indexes were then developed for several precipitation period combinations for each site.

Equations (1) and (2) were then used to determine which precipitation periods best represented each site. The most representative precipitation periods are shown in Table 2.a.1, and the best fit yield relationship, developed from equation (1) is:

Table 2.a.2.--Herbage yield of untreated and grazed plots(lbs/acre, air dry weight).

			71	72	73	74	75	76	77	78	79	MEAN
Flats	Total	Ungrazed	556	424	---	559	437	446	193	1960	466	630 ^{1/}
		Grazed	851	663	---	649	710	593	263	2061	630	803
	No Shrubs ^{2/}	Ungrazed	511	216	---	398	343	367	70	1345	304	444
		Grazed	664	207	---	444	522	398	101	736	291	421
Whiskey Hill	Total	Ungrazed	---	805	879	1076	1044	830	1093	1805	1055	1073
		Grazed	---	1360	888	769	1754	1030	1759	1790	1414	1347
	No Shrubs	Ungrazed	---	211	393	618	679	672	588	1218	818	650
		Grazed	---	355	300	369	673	638	420	790	634	522
Nancy	Total	Ungrazed	404	677	1019	978	608	564	198	590	569	623
		Grazed	604	454	1202	894	667	759	465	836	963	760
	No Shrubs	Ungrazed	373	230	648	378	450	398	68	362	299	356
		Grazed	393	139	523	502	426	500	81	315	389	363
L. Sheep	Total	Ungrazed	852	339	---	599	688	542	138	1179	525	608
		Grazed	819	439	---	648	687	387	350	745	718	599
	No Shrubs	Ungrazed	700	156	---	313	339	261	66	471	272	322 ^{1/}
		Grazed	502	143	---	105	247	156	54	147	229	198
Nettleton	Total	Ungrazed	1952	537	1018	975	1514	879	890	1746	780	1143
		Grazed	1287	472	1354	1058	804	932	460	1211	631	912
	No Shrubs	Ungrazed	1791	388	975	912	1107	725	812	1477	695	987 ^{1/}
		Grazed	1183	332	887	918	425	811	425	765	525	697
Upper Sheep (sparse)	Total	Ungrazed	558	614	---	352	521	303	688	775	453	533
		Grazed	594	488	---	336	568	755	609	588	663	575
	No Shrubs	Ungrazed	420	165	---	81	155	99	224	540	179	233
		Grazed	468	164	---	58	118	200	109	173	322	201
Upper Sheep (dense)	Total	Ungrazed	2115	1631	2166	1509	1424	612	1493	3329	1420	1744
		Grazed	2853	1586	1171	2105	1267	1196	1452	2666	1634	1770
	No Shrubs	Ungrazed	1690	387	687	441	407	254	1322	3227	1349	1085
		Grazed	2336	643	590	916	503	517	1318	2041	1272	1126
Reynolds Mtn. (sparse)	Total	Ungrazed	699	451	---	596	830	790	447	655	487	619
		Grazed	927	362	---	859	688	610	605	693	690	679
	No Shrubs	Ungrazed	660	130	---	266	346	423	318	428	346	365
		Grazed	896	217	---	387	386	290	469	377	435	432
Reynolds Mtn. (dense)	Total	Ungrazed	1283	1924	2028	1462	1747	589	885	2198	1121	1471
		Grazed	1516	986	1348	1204	1733	1579	1119	1305	864	1294
	No Shrubs	Ungrazed	907	365	426	474	349	266	763	959	877	598
		Grazed	914	279	255	328	434	249	411	1102	686	518

^{1/} Annual means are significantly different at the 5% level.^{2/} The yields of shrub species not included.

$$Y_H = (X_{H1} + X_{H2}) 0.555 - 10.6 \quad (3)$$

where, Y_H is the yield index (%) for the sites at 5500 feet and above, X_{H1} is the precipitation index (%) of the winter precipitation period, and X_{H2} is the precipitation index (%) of the spring precipitation.

The relationship between the measured and computed yields, using equation (3) are shown on Figure 2.a.2. The slope of the line on Figure 2.a.2 is not significantly different from 1.0, and the intercept is not significantly different from zero, which is an indication of how well equation (3) represented the study sites at 5500 feet and above. The yields computed, using equation (2) as the basic model, were higher than measured for all sites.

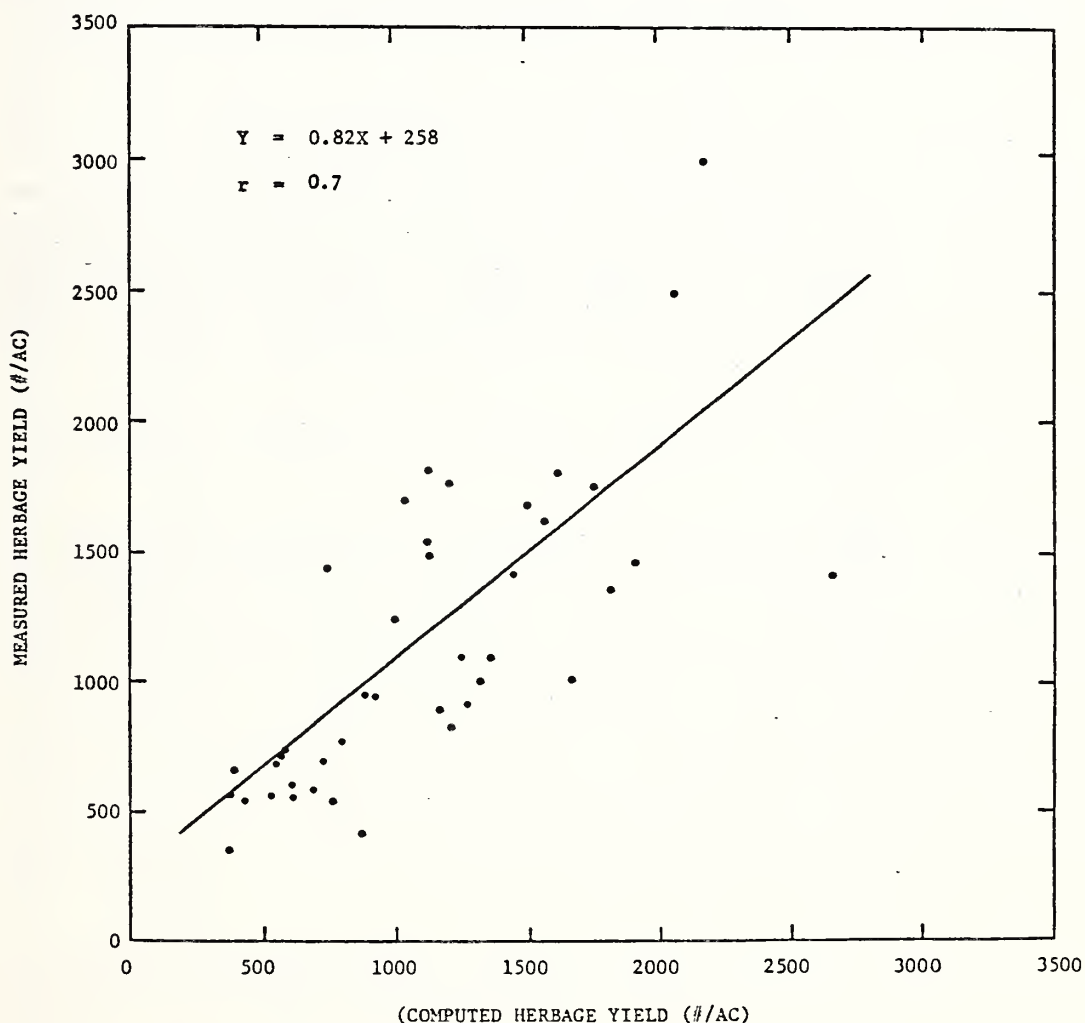


Figure 2.a.2.-- Relationship between measured and computed herbage yield using the Sneva and Hyder model for the high elevation study sites.

As shown in Table 2.a.1, the effective precipitation period varied from November through April at two sites, to November through May at the other two low elevation sites. As would be expected, this difference appears to be associated with harvest dates. At the higher elevation sites, such as Upper Sheep Creek, there were two effective precipitation periods, one associated with winter precipitation and one associated with spring snow and rain. The precipitation periods at the high elevation sites showed the same trend as the low elevation sites with the effective precipitation periods extending later into the summer with increasing elevation. The fact that snow accumulated on the Upper Sheep Creek (dense) and the Reynolds Mountain (dense) sites, increased the herbage yields, but the effective precipitation periods were the same as the sparse study sites at the same elevation.

Basal cover for 1979: The following sections are presented in support of the erosion studies that are discussed later in this report. Basal cover on eight study sites for the 1979 growing season is listed in Table 2.a.3. The average grass cover was greater on the ungrazed

Table 2.a.3.—Basal cover from eight study sites on Reynolds Creek Watershed in 1979.

Site	Treatment	% Grasses	% Forbes	% Shrubs	% Litter	% Rock	% Bare Ground
Flats	Ungrazed	4	2	T ^{2/}	53	4	37
	Grazed	2	2	1	30	11	54
Whiskey Hill	Ungrazed	11	2	1	56	4	26
	Grazed	5	2	1	54	6	32
Nancy Gulch	Ungrazed	9	4	1	31	19	36
	Grazed	10	6	1	30	17	36
Lower Sheep Creek	Ungrazed	10	2	1	34	29	24
	Grazed	12	1	3	29	31	24
Upper Sheep Creek (sparse)	Ungrazed	7	1	2	24	32	34
	Grazed	6	1	1	18	34	40
Upper Sheep Creek (dense)	Ungrazed	7	2	2	86	T	3
	Grazed	6	4	T	72	1	17
Reynolds Mountain (sparse)	Ungrazed	7	6	T	27	45	15
	Grazed	5	9	T	27	41	18
Reynolds Mountain (dense)	Ungrazed	6	1	1	70	3	19
	Grazed	3	2	T	66	4	25
1979 Average	Ungrazed	8 ^{1/}	2	1	48 ^{3/}	17	24
	Grazed	6	3	1	41	18	31 ^{4/}

^{1/} The ungrazed and grazed treatments were not significantly different ($P < 0.05$)

^{2/} Trace

^{3/} The ungrazed average litter was significantly greater ($P < 0.05$) than the grazed treatment.

^{4/} The grazed treatment bare ground was significantly greater ($P < 0.05$) than the associated untreated areas.

treatment than on the associated grazed areas, except at Nancy Gulch and Lower Sheep Creek. The average basal grass cover was greater on the ungrazed plots than on the associated grazed areas, but not significantly greater ($P < 0.05$). On four of the eight sites, there was more forb cover on the grazed than on the ungrazed areas. The average forb cover was greater on the grazed treatment. The average litter cover was significantly greater on the ungrazed plots than on the adjacent grazed areas. There was less bare ground on six of the eight ungrazed plots than on the associated grazed areas. The average bare ground on the ungrazed plots was significantly less than on the grazed areas.

Basal cover for 1972 through 1979: Tables 2.a.4 through 2.a.12 are summaries of the basal cover by year on the nine sites. Average grass cover on the ungrazed plot was as much or more on all sites, but was significantly greater ($P < 0.05$) only at the two Upper Sheep sites and the dense cover site at Reynolds Mountain. Forbs accounted for 12 percent or less of the cover at all sites. The average forb cover was significantly different only at the Upper Sheep Creek (dense) site where the grazed area had more forbs. Average shrub cover accounted for 4 percent or less of the cover at all sites. Average litter cover ranged from 12 percent on the grazed Upper Sheep Creek (sparse) site to 69 percent on the ungrazed Upper Sheep Creek (dense) site. The average litter cover was significantly greater on the ungrazed plot at the Upper Sheep Creek (sparse) and Nettleton sites. Average bare ground was greater on all grazed areas than on the associated ungrazed plots, but was significantly greater at only four of the locations. The average bare ground ranged from 57 percent on the grazed area at the Flats to only 8 percent on the ungrazed plot at the Upper Sheep Creek (dense) site.

These analyses indicate that there is more grass cover, more litter cover, and less bare ground on the ungrazed areas than on the adjacent grazed areas.

Basal and canopy cover of selected species for 1972 through 1979: One of the reasons for establishing the grazing study areas in 1971 on the Reynolds Creek Watershed was to find out what effect excluding grazing would have on range condition. Tables 2.a.13 and 2.a.14 are summaries of basal and canopy cover of selected species at each of the nine study sites for the period 1972 through 1979. These data are based on 700 points per treatment (ungrazed and grazed) at each site each year. Only one canopy contact was recorded per species per pin, with a limit of three species per pin. At the Upper Sheep Creek (dense) and Reynolds Mountain (dense) sites there were a few points per plot when there were actually four or five species hit per pin, but only the first three hits from the top were recorded.

As can be seen from these tables, no trend toward improved cover has developed due to fencing the plots except at the Nettleton plots. In general, there is more grass cover on the ungrazed plots, but there is no trend toward improved condition except at the Nettleton plots. Here, the Bottlebrush squirreltail cover is greater on the ungrazed plot and the Sandberg bluegrass cover is greater on the grazed plot. The cover differences at Nettletons are associated with the very heavy grazing on the grazed plot and no grazing on the other plot.

Table 2.a.4.—Basal cover at the time of peak standing crop at the Flats study site for 1972 through 1979.

	<u>Grasses</u>		<u>Forbs</u> ^{2/}		<u>Shrubs</u>		<u>Litter</u>		<u>Rock</u>		<u>Bare Ground</u>	
	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed
1972	11	12	3	5	0	T	31	24	6	10	49	49
1973	2	2	4	5	1	1	33	29	6	10	54	53
1974	17	9	5	5	1	1	38	37	4	8	35	40
1975	17	15	3	3	1	1	3	4	8	13	68	64
1976	2	1	0	0	T	0	5	12	9	14	84	73
1977	3	2	T ^{3/}	0	2	1	47	26	5	12	43	59
1978	21	9	1	1	1	2	19	14	6	12	52	62
1979	4	2	2	2	T	1	53	30	4	11	37	54
Average	10 ^a ^{1/}	6 ^a	2	3	1	1	28 ^a	22 ^a	6 ^a	11 ^b	53 ^a	57 ^a

^{1/} Means within each cover type with the same letter are not significantly different at the 0.05 probability level.

^{2/} The Forb and shrub means were not analyzed statistically.

^{3/} Trace

Table 2.a.5.—Basal cover at the time of peak standing crop at the Whiskey Hill site for 1972 through 1979.

	<u>Grasses</u>		<u>Forbs</u> ^{2/}		<u>Shrubs</u>		<u>Litter</u>		<u>Rock</u>		<u>Bare Ground</u>	
	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed
1972	20	26	10	6	2	3	35	30	5	5	28	30
1973	5	19	1	4	3	1	54	45	5	5	32	26
1974	17	12	6	2	1	3	45	44	4	6	27	33
1975	20	14	8	3	2	4	41	46	4	5	25	28
1976	4	5	T ^{3/}	5	1	3	55	57	6	5	34	25
1977	17	10	14	4	2	5	31	47	5	5	31	29
1978	8	6	2	2	1	2	38	51	4	6	27	33
1979	11	5	2	2	1	1	56	54	4	6	26	32
Average	13 ^a ^{1/}	12 ^a	5	3	2	3	47 ^a	47 ^a	4 ^a	5 ^a	29 ^a	30 ^a

^{1/} Means within each cover type with the same letter are not significantly different at the 0.05 probability level.

^{2/} The Forb and shrub means were not analyzed statistically.

^{3/} Trace

Table 2.a.6.--Basal cover at the time of peak standing crop at the Nancy Gulch site for 1972 through 1979.

	<u>Grasses</u>		<u>Forbs</u>		<u>Shrubs</u> ^{2/}		<u>Litter</u>		<u>Rock</u>		<u>Bare Ground</u>	
	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed
1972	13	19	2	5	.0	T ^{3/}	26	27	20	16	39	33
1973	12	7	21	20	1	1	16	11	17	20	33	41
1974	18	14	11	20	1	1	23	13	16	17	31	35
1975	12	12	23	19	1	1	19	14	15	17	30	37
1976	3	3	5	11	T	T	37	34	19	17	36	35
1977	6	4	3	4	2	2	39	41	17	16	33	33
1978	8	9	13	9	1	1	19	19	20	20	39	42
1979	9	10	4	6	1	1	31	30	19	17	36	36
Average	10 ^{a 1/}	10 ^a	10 ^a	12 ^a	1	1	26 ^a	24 ^a	18 ^a	17 ^a	35 ^a	36 ^a

^{1/} Means within each cover type with the same letter are not significantly different at the 0.05 probability level.

^{2/} Shrubs were not analyzed statistically.

^{3/} Trace

Table 2.a.7.--Basal cover at the time of peak standing crop at the Lower Sheep study site for 1972 through 1979.

	<u>Grasses</u>		<u>Forbs</u>		<u>Shrubs</u> ^{2/}		<u>Litter</u>		<u>Rock</u>		<u>Bare Ground</u>	
	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed
1972	17	16	4	4	T ^{3/}	T	25	25	30	31	24	24
1973												
1974	19	17	3	5	3	2	21	18	30	33	24	25
1975	12	15	33	16	6	5	5	5	24	33	20	26
1976	4	6	5	6	1	1	31	30	32	32	27	25
1977	37	29	19	13	1	3	7	5	20	28	16	22
1978	8	13	3	3	2	3	35	26	29	31	23	24
1979	10	12	2	1	1	3	34	29	29	31	24	24
Average	15 ^{a 1/}	15 ^a	10 ^a	7 ^a	2	3	23 ^a	20 ^a	28 ^a	31 ^b	22 ^a	24 ^a

^{1/} Means within each cover type with the same letter are not significantly different at the 0.05 probability level.

^{2/} Shrubs were not analyzed statistically.

^{3/} Trace

Table 2.a.8.--Basal cover at the time of peak standing crop at the Nettleton study site for 1972 through 1979.

	<u>Grasses</u>		<u>Forbs</u> ^{3/}		<u>Shrubs</u>		<u>Litter</u>		<u>Rock</u>		<u>Bare Ground</u>	
	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed
1972 ^{1/}	24	24	2	2	0	0	33	33	13	13	28	28
1973	23	29	2	0	1	1	43	30	9	12	22	28
1974	27	10	2	1	1	T	47	51	7	11	16	27
1975	40	19	3	2	3	3	39	29	4	14	11	33
1976	5	3	1	3	1	1	59	39	10	16	24	38
1977	25	21	2	1	1	1	47	40	7	11	18	26
1978	10	19	1	4	1	1	70	28	5	14	13	34
1979	6	13	1	T ^{4/}	1	1	78	39	4	14	10	33
Average	20 ^{a2/}	17 ^a	2	2	1	1	52 ^a	36 ^b	7 ^a	13 ^b	18 ^a	31 ^b

^{1/} Data obtained prior to the first years grazing.

^{2/} Means within each cover type with the same letter are not significantly different at the 0.05 probability level.

^{3/} The Forb and shrub means were not analyzed statistically.

^{4/} Trace

Table 2.a.9.--Basal cover at the time of peak standing crop at the Upper Sheep Creek (sparse) study site for 1972 through 1979.

	<u>Grasses</u>		<u>Forbs</u> ^{2/}		<u>Shrubs</u>		<u>Litter</u>		<u>Rock</u>		<u>Bare Ground</u>	
	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed
1972	14	9	4	2	2	1	18	16	30	33	32	39
1973												
1974	7	6	1	1	2	3	14	9	37	37	39	44
1975	6	3	4	2	13	6	8	8	33	37	36	44
1976	4	3	T ^{3/}	1	1	1	13	8	40	40	42	47
1977	12	9	2	2	9	6	8	4	33	36	36	43
1978	7	7	1	1	2	2	24	18	32	33	34	39
1979	7	6	1	1	2	1	24	18	32	34	34	40
Average	8 ^{a1/}	6 ^b	2	1	4 ^a	3 ^a	16 ^a	12 ^b	34 ^a	36 ^b	36 ^a	42 ^b

^{1/} Means within each cover type with the same letter are not significantly different at the 0.05 probability level.

^{2/} The Forb means were not analyzed statistically.

^{3/} Trace

Table 2.a.10.--Basal cover at the time of peak standing crop at the Upper Sheep Creek (dense) study site for 1972 through 1979.

	<u>Grasses</u>		<u>Forbs</u>		<u>Shrubs</u> ^{2/}		<u>Litter</u>		<u>Rock</u>		<u>Bare Ground</u>	
	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed
1972	38	32	14	23	T ^{3/}	1	11	33	1	1	6	10
1973	13	10	4	6	3	4	65	62	1	1	14	17
1974	25	4	4	16	4	3	55	59	1	1	11	17
1975	7	3	2	6	T	4	83	71	1	1	7	15
1976	1	1	2	3	T	0	88	73	1	1	8	22
1977	12	6	6	10	1	1	66	71	1	1	14	11
1978	24	9	8	11	1	1	63	61	1	1	3	17
1979	7	6	2	4	2	T	86	72	T	1	3	17
Average	16 ^{a1/}	9 ^b	5 ^a	10 ^b	1	2	69 ^a	63 ^a	1	1	8 ^a	15 ^b

^{1/} Means within each cover type with the same letter are not significantly different at the 0.05 probability level.

^{2/} The shrub and rock means were not analyzed statistically.

^{3/} Trace

Table 2.a.11.--Basal cover at the time of peak standing crop at the Reynolds Mountain (sparse) study site for 1972 through 1979.

	<u>Grasses</u>		<u>Forbs</u>		<u>Shrubs</u> ^{2/}		<u>Litter</u>		<u>Rock</u>		<u>Bare Ground</u>	
	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed
1972	13	9	4	6	T ^{3/}	0	16	19	50	46	17	20
1973												
1974	9	13	8	8	1	1	17	13	49	45	16	20
1975	11	10	9	10	3	4	8	10	52	46	17	20
1976	10	11	3	4	1	1	9	21	58	44	19	19
1977	12	12	15	13	1	T	20	23	39	36	13	16
1978	5	6	7	9	1	T	22	30	49	38	16	17
1979	7	5	6	9	T	T	27	27	45	41	15	18
Average	10 ^{a1/}	9 ^a	7 ^a	8 ^a	1	1	17 ^a	21 ^a	49 ^a	42 ^b	16 ^a	19 ^b

^{1/} Means within each cover type with the same letter are not significantly different at the 0.05 probability level.

^{2/} The shrub means were not analyzed statistically.

^{3/} Trace

Table 2.a.12.--Basal cover at the time of peak standing crop at the Reynolds Mountain (dense) study site for 1972 through 1979.

	<u>Grasses</u>		<u>Forbs</u>		<u>Shrubs</u> ^{2/}		<u>Litter</u>		<u>Rock</u>		<u>Bare Ground</u>	
	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed
1972	23	17	18	19	1	2	40	42	3	3	15	17
1973	21	4	8	3	4	4	45	64	3	4	19	21
1974	14	10	7	6	1	1	45	54	5	4	28	25
1975	12	14	5	8	3	3	57	49	4	4	19	22
1976	22	14	25	21	4	3	36	31	2	5	11	26
1977	27	12	8	2	T ^{3/}	T	49	62	2	4	14	20
1978	10	3	4	3	1	T	69	75	2	3	14	16
1979	6	3	1	2	1	T	70	66	3	4	19	25
Average	17 ^{a1/}	10 ^b	10 ^a	8 ^a	2	2	51 ^a	55 ^a	3 ^a	4 ^a	17 ^a	21 ^a

^{1/} Means within each cover type with the same letter are not significantly different at the 0.05 probability level.

^{2/} The shrub means were not analyzed statistically.

^{3/} Trace

The forb and brush cover at each site does not show any trend toward changing range condition due to fencing. The sagebrush kill during the winter of 1976 and 1977 is very evident in the canopy cover data on the Upper Sheep Creek (dense) and the Reynolds Mountain (dense) sites.

Nettleton study site: The effects of heavy grazing since 1971 at the Nettleton site are shown in Tables 2.a.2, 2.a.8, 2.a.13, 2.a.14, and 2.a.15.

Seven cows and seven calves were turned into the grazed area on June 11, 1979, and were removed on June 19, 1979, when the major species showed at least 80 percent utilization. Randomly placed caged plots served as harvest areas, since harvest was completed after cattle had grazed the area.

Both total herbage yield and herbage yield of species other than shrubs, were greater in the ungrazed enclosure than in the grazed enclosure (Table 2.a.2). These data would suggest that, under this grazing system, about seven years were required before herbage yields in the ungrazed enclosure became greater than in the heavily grazed enclosure.

Cover measurements of selected species for 1972-79 are shown in Tables 2.a.14 and 2.a.15. The data suggests that Bottlebrush squirreltail is increasing under no grazing and staying about the same with heavy grazing. Sandberg bluegrass is decreasing with no grazing and increasing

Table 2.a.13.—Basal cover of selected species from nine study sites on Reynolds Creek watershed, 1972-1979.

SITE	TREATMENT	SPECIES	72	73	74	75	76	77	78	79
Flata	Ungrazed	Bottlebrush squirreltail	2.6	0.3	2.4	1.6	0.3	2.7	1.9	2.0
		Cheatgrass	8.1	2.1	14.8	15.3	0.1	0.3	18.7	2.0
		Shadscale	—	0.9	1.0	0.6	0.1	2.4	1.1	0.4
	Grazed	Bottlebrush squirreltail	4.1	0.1	1.7	1.0	—	2.0	0.4	0.6
		Cheatgrass	7.7	1.7	7.3	14.1	0.7	0.3	8.3	1.4
		Shadscale	0.1	0.7	1.2	1.1	—	0.4	0.7	0.4
Whiskey Hill	Ungrazed	Bottlebrush squirreltail	2.0	—	1.6	2.0	0.3	4.2	0.6	1.2
		Sandberg bluegrass	5.0	2.7	3.6	1.2	1.3	3.0	1.8	2.8
		Big sagebrush	0.3	2.4	0.8	0.2	0.4	0.8	0.6	0.4
	Grazed	Bottlebrush squirreltail	3.3	3.3	1.6	2.0	0.7	2.4	0.8	0.2
		Sandberg bluegrass	9.9	10.4	3.2	6.4	1.4	4.8	2.8	4.2
		Big sagebrush	0.3	0.4	1.6	2.0	2.1	2.4	1.8	1.0
Nancy Gulch	Ungrazed	Bottlebrush squirreltail	2.7	0.8	1.7	1.7	0.4	1.4	1.0	0.9
		Sandberg bluegrass	8.9	10.4	16.0	9.5	2.6	3.9	7.3	8.3
		Big sagebrush	—	0.5	0.7	1.4	0.3	2.0	1.4	1.0
	Grazed	Bottlebrush squirreltail	2.4	0.2	1.0	0.6	—	0.4	0.1	0.1
		Sandberg bluegrass	14.9	6.2	13.3	11.0	2.6	3.3	8.9	9.6
		Big Sagebrush	0.1	0.8	0.9	1.0	0.3	1.6	1.0	1.0
Lower Sheep Creek	Ungrazed	Sandberg bluegrass	13.9	—	17.7	12.0	3.9	29.9	7.9	9.3
		Low sagebrush	0.4	—	2.6	6.0	1.0	1.3	1.9	1.3
	Grazed	Sandberg bluegrass	14.7	—	16.9	15.0	5.9	29.2	12.6	11.9
		Low sagebrush	0.1	—	1.7	4.4	0.7	2.1	3.0	3.1
Nettletons	Ungrazed	Bottlebrush squirreltail	2.6 ^{1/}	3.0	2.6	0.4	1.0	2.0	1.0	0.6
		Sandberg bluegrass	10.1	13.4	14.7	12.3	2.6	10.1	2.9	3.0
		Cheatgrass	11.3	5.4	8.1	23.9	0.7	10.1	3.9	0.1
		Big sagebrush	—	—	0.6	1.4	0.6	1.0	0.7	0
	Grazed	Bottlebrush squirreltail	2.6 ^{1/}	3.2	0.4	0.4	0.4	3.0	1.3	0.4
		Sandberg bluegrass	10.1	21.0	9.4	13.2	3.0	14.0	14.7	12.4
		Cheatgrass	11.3	4.7	0.4	5.3	—	4.0	2.9	0
		Big sagebrush	—	0.5	0.3	2.1	0.9	1.0	0.9	0
Upper Sheep Creek (sparse)	Ungrazed	Sandberg bluegrass	12.1	—	7.0	5.3	3.4	11.3	6.9	7.1
		Low sagebrush	1.1	—	1.9	9.1	1.1	7.1	1.9	1.3
	Grazed	Sandberg bluegrass	8.1	—	5.7	3.4	3.0	8.6	7.0	5.4
		Low sagebrush	0.4	—	2.3	4.0	0.7	4.0	1.3	0.7
Upper Sheep Creek (dense)	Ungrazed	Bottlebrush squirreltail	9.6	2.1	6.6	1.0	0.4	3.2	4.4	0.7
		Needlegrass	8.6	3.5	3.6	1.6	0.2	1.3	3.1	0.1
		Big sagebrush	—	2.3	2.9	0.1	—	0.4	0.7	1.0
	Grazed	Bottlebrush squirreltail	8.8	1.7	2.3	0.2	—	1.9	2.0	1.4
		Needlegrass	10.0	3.6	1.4	2.6	—	0.6	2.6	1.8
		Big sagebrush	—	2.9	1.0	2.8	—	0.3	0.3	0
Reynolds Mountain (sparse)	Ungrazed	Sandberg bluegrass	—	—	0.1	—	0.9	3.7	0.4	2.0
		Sedge	4.1	—	1.9	4.3	7.9	0.3	1.7	1.0
		Idaho fescue	3.1	—	1.7	2.4	1.1	4.4	2.6	2.7
		Big sagebrush	—	—	0.7	2.6	1.0	—	0.4	0.3
	Grazed	Sandberg bluegrass	—	—	—	—	—	6.0	2.1	2.0
		Sedge	3.0	—	—	2.7	6.1	0.3	1.9	0.9
		Idaho fescue	1.1	—	2.1	2.1	2.3	1.6	0.1	1.0
		Big sagebrush	—	—	0.9	3.9	0.6	—	0.1	0.4
Reynolds Mountain (dense)	Ungrazed	Needlegrass	4.7	4.0	2.0	2.0	0.3	0.8	2.4	0.4
		Bluegrass	2.8	1.7	—	0.2	0.5	3.8	3.2	0.8
		Big mountain brome	3.6	4.2	1.2	0.6	1.0	2.4	1.2	0.8
		Lupine	6.3	4.0	2.0	1.4	13.1	0.4	0.2	0.2
		Big sagebrush	—	4.0	0.8	3.4	2.8	0.2	0.6	0.8
	Grazed	Needlegrass	1.9	—	1.2	5.0	2.3	0.4	0.2	0.2
		Bluegrass	4.0	1.3	1.2	1.0	1.8	1.0	0.2	0.8
		Big mountain brome	5.0	0.4	1.6	1.4	2.3	1.4	0.8	1.2
		Lupine	2.1	0.8	2.2	1.2	12.4	0.2	0.4	0.6
		Big sagebrush	0.1	3.4	0.6	3.2	0.8	0.2	—	0.2

^{1/} Point data taken before grazing study started.

Table 2.a.14.--Canopy cover of selected species from nine sites on Reynolds Creek watershed, 1972-1979.

SITE	TREATMENT	SPECIES	72	73	74	75	76	77	78	79
Flats	Ungrazed	Bottlebrush squirreltail	1.0	2.8	5.8	5.0	3.4	3.3	7.8	17.6
		Cheatgrass	25.2	30.0	20.0	21.1	45.8	0.3	27.5	8.0
		Shadscale	11.9	0.6	7.6	4.4	7.8	9.7	8.4	5.1
	Grazed	Bottlebrush squirreltail	0.7	0.6	3.3	1.5	0.3	1.4	1.4	2.3
		Cheatgrass	18.6	16.0	10.6	23.5	47.4	0.1	13.7	2.8
		Shadscale	13.6	9.2	7.0	3.4	6.7	5.5	6.7	4.8
Whiskey Hill	Ungrazed	Bottlebrush squirreltail	1.0	0.2	6.4	4.4	5.2	5.0	7.6	2.0
		Sandberg bluegrass	4.4	3.7	4.8	3.0	9.1	1.8	2.8	2.8
		Big sagebrush	39.8	29.0	14.8	27.4	17.6	20.8	14.2	13.4
	Grazed	Bottlebrush squirreltail	1.2	1.4	6.7	3.4	4.7	4.6	5.2	0.6
		Sandberg bluegrass	4.4	4.3	5.2	5.8	4.3	3.8	4.6	5.6
		Big sagebrush	40.4	30.8	15.8	30.0	29.2	26.4	19.6	16.8
Nancy Gulch	Ungrazed	Bottlebrush squirreltail	2.8	2.7	4.0	3.9	3.8	1.7	4.3	3.0
		Sandberg bluegrass	17.1	14.9	16.9	28.5	45.2	3.7	14.9	15.2
		Big sagebrush	18.3	15.6	8.4	12.3	9.9	10.9	10.2	8.6
	Grazed	Bottlebrush squirreltail	1.2	0.9	1.0	1.2	2.3	0.5	0.8	1.1
		Sandberg bluegrass	19.0	11.2	13.2	27.8	37.2	3.6	15.7	14.8
		Big sagebrush	17.8	12.6	9.4	13.0	12.6	9.5	6.7	12.7
Lower Sheep Creek	Ungrazed	Sandberg bluegrass	20.0	NA	15.5	19.0	30.2	21.1	10.5	10.6
		Low sagebrush	30.0	NA	19.3	26.1	28.8	16.3	23.9	23.8
	Grazed	Sandberg bluegrass	21.5	NA	14.1	15.6	38.4	16.6	11.5	11.6
		Low sagebrush	25.9	NA	19.5	25.1	24.4	21.4	21.9	24.2
Nettletons	Ungrazed	Bottlebrush squirreltail	6.6	4.1	6.7	0.7	7.3	4.0	8.1	9.6
		Sandberg bluegrass	18.9	19.3	20.5	26.1	28.0	9.1	8.7	3.0
		Cheatgrass	16.1	7.7	17.6	25.1	20.2	29.3	49.6	6.1
		Big sagebrush	11.1	0.5	5.7	6.6	8.4	6.1	5.2	0.7
	Grazed	Bottlebrush squirreltail	6.6	2.0	1.8	1.3	4.5	3.0	5.9	5.7
		Sandberg bluegrass	18.9	17.1	10.0	31.0	50.3	14.0	45.8	23.1
		Cheatgrass	16.1	1.5	5.0	8.8	6.9	15.0	20.0	3.0
		Big sagebrush	11.1	5.5	5.3	12.9	6.0	7.0	6.3	0.9
Upper Sheep Creek (sparse)	Ungrazed	Sandberg bluegrass	14.5	NA	9.4	9.6	22.1	10.7	11.7	12.6
		Low sagebrush	24.9	NA	19.8	18.7	23.3	23.3	22.6	18.4
	Grazed	Sandberg bluegrass	9.5	NA	6.0	8.7	19.5	11.6	13.2	13.0
		Low sagebrush	18.7	NA	13.6	17.3	16.2	19.0	18.5	15.9
Upper Sheep Creek (dense)	Ungrazed	Bottlebrush squirreltail	6.0	4.6	9.5	6.9	4.4	14.4	15.7	4.2
		Needlegrass	2.1	5.8	5.3	5.8	2.4	4.2	9.5	0.9
		Big sagebrush	47.4	30.4	29.9	30.5	37.2	8.2	7.1	6.6
	Grazed	Bottlebrush squirreltail	2.1	1.1	1.7	0.8	0.4	3.5	8.2	6.8
		Needlegrass	1.2	3.0	0.8	3.4	1.2	3.5	4.7	0.3
		Big sagebrush	45.8	25.2	35.0	38.2	39.4	4.9	3.2	2.6
	Ungrazed	Sandberg bluegrass	---	NA	0.1	---	---	3.3	2.0	2.5
		Sedge	5.1	NA	3.0	4.1	9.4	0.7	3.8	2.3
		Idaho fescue	4.2	NA	3.2	3.6	2.0	3.5	8.9	4.7
		Big sagebrush	22.7	NA	14.3	17.0	18.6	9.4	9.4	9.5
Reynolds Mountain (sparse)	Grazed	Sandberg bluegrass	---	NA	---	---	---	6.2	4.8	4.4
		Sedge	4.2	NA	---	2.5	5.3	0.4	2.9	1.7
		Idaho fescue	2.9	NA	2.1	3.5	4.4	1.7	6.1	3.1
		Big sagebrush	22.4	NA	10.3	15.1	22.2	8.9	7.8	9.9
	Ungrazed	Needlegrass	2.3	0.8	2.4	4.8	0.8	2.0	6.0	7.4
		Bluegrass	0.8	0.6	---	1.2	1.8	5.0	5.6	4.2
		Big mountain brome	1.3	1.3	1.6	2.2	5.9	11.2	15.0	7.6
		Lupine	7.8	11.2	10.4	11.4	12.0	8.0	11.2	11.2
Reynolds Mountain (dense)	Ungrazed	Big sagebrush	59.4	48.2	45.6	42.2	58.6	10.6	16.0	15.2
		Needlegrass	2.3	0.6	1.0	5.8	1.0	1.0	3.4	2.0
		Bluegrass	2.3	1.0	1.2	2.0	1.0	4.8	3.8	3.2
		Big mountain brome	4.4	1.5	2.8	1.8	2.3	20.0	30.0	12.8
	Grazed	Lupine	4.1	9.0	8.8	8.6	11.6	18.0	7.8	7.4
		Big sagebrush	48.4	43.0	32.2	49.2	61.0	6.4	7.8	8.2

under heavy grazing. In 1979, litter accounted for 78 and 39 percent of the basal cover on the ungrazed and grazed treatments, respectively (Table 2.a.15). Bare ground accounted for 10 percent of the basal cover on the ungrazed treatment and 33 percent on the grazed treatment.

Table 2.a.15.--1979 basal cover at Nettleton study site

Treatment	% Grasses	% Forbs	% Shrubs	% Litter	% Rock	% Bare Ground
Ungrazed	6	1	1	78	4	10
Grazed	13	1 ^{1/}	1	39	14	33

^{1/}Trace

Fall basal cover: Basal cover measurements, summarized in Table 2.a.16, were obtained during the fall in an effort to determine the effects of cover on erosion caused by winter runoff. These measurements were done, using the same method described under the previous cover sections.

The average litter cover was greater on the ungrazed plots than the associated grazed areas at all sites except the two Reynolds Mountain sites, where the differences were very small. The amount of bare ground was greater on all grazed areas than on the adjacent ungrazed plot, except at the Reynolds Mountain dense site, where the difference was only 1 percent.

Table 2.a.16.—Basal cover measured during the fall at nine study sites for 1974, 1975, 1978, and 1979.

	<u>Grasses</u>		<u>Forbs</u>		<u>Shrubs</u>		<u>Litter</u>		<u>Rock</u>		<u>Bare Ground</u>	
	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed
FLATS												
1974	0	0	0	0	T	1	56	55	5	7	39	37
1975	4	2	2	3	3	1	45	36	5	10	41	48
1978	0	0	T	2	1	1	65	33	3	11	31	53
1979	T 1/	0	0	0	0	0	64	45	4	9	32	46
Average	1	1	T	1	1	1	58	42	4	9	36	46
WHISKEY HILL												
1974	0	0	1	1	0	0	63	64	5	5	31	30
1975	11	11	3	1	2	3	62	60	3	4	19	21
1978	3	2	T	T	2	2	78	76	2	3	15	17
1979	1	0	0	0	0	0	87	76	2	4	10	20
Average	4	3	1	1	1	1	72	69	3	4	19	22
NANCY GULCH												
1974	0	0	0	0	1	1	51	39	16	19	32	41
1975	14	12	15	16	2	1	26	20	15	16	28	35
1978	6	4	0	0	2	1	43	44	17	16	32	35
1979	2	8	T	T	T	1	58	50	14	13	26	28
Average	5	6	4	4	1	1	44	38	16	16	30	35
LOWER SHEEP												
1975	16	14	15	10	1	2	17	19	28	31	23	24
1978	6	8	T	0	2	2	45	44	26	26	21	20
1979	T	0	0	0	0	T	60	54	22	26	18	20
Average	7	7	5	3	1	1	41	39	25	28	21	22
NETTLETON												
1975	27	14	3	1	1	3	55	45	4	11	10	26
1978	0	0	T	0	1	T	82	60	5	12	12	28
1979	T	0	0	0	0	T	89	58	3	13	8	29
Average	9	5	1	T	1	1	75	54	4	12	10	28
UPPER SHEEP CREEK (Sparse)												
1975	7	6	1	1	3	3	17	8	35	38	37	44
1978	4	4	0	T	2	2	29	22	31	33	34	39
1979	1	T	0	0	T	T	37	32	30	31	32	37
Average	4	3	T	T	2	2	28	21	32	34	34	40
UPPER SHEEP CREEK (Dense)												
1978	1	6	0	T	1	T	94	81	T	1	4	12
1979	1	T	0	0	0	0	97	92	T	T	2	8
Average	1	3	0	T	T	T	96	86	T	1	3	10
REYNOLDS MOUNTAIN (Sparse)												
1974	0	0	0	0	0	0	48	47	39	37	13	16
1978	2	1	2	3	1	1	45	47	38	33	12	15
1979	2	4	3	5	1	T	30	38	48	37	16	16
Average	1	2	2	3	1	T	41	44	41	35	14	16
REYNOLDS MOUNTAIN (Dense)												
1974	8	6	0	0	0	1	50	68	6	4	36	21
1978	4	5	2	1	1	T	79	75	2	3	12	16
1979	2	1	1	0	0	T	84	77	2	3	11	19
Average	5	4	1	T	T	T	71	74	3	3	20	19

1/ Trace

References: Section 2.a

Sneva, F. A., and D. N. Hyder. 1962a. Forecasting range herbage production in eastern Oregon. Oregon Agr. Exp. Sta. Bull. 558, Corvallis, Oregon. 11 pp.

Sneva, F. A., and D. N. Hyder. 1962b. Estimating herbage production on semiarid ranges in the intermountain region. J. Range Manage. 15(2): 88-93.

b. Boise Front

(Boise Front Watershed study site locations are shown on Introduction, Figure 2. Pastures are referred to throughout the report as H(High) and L(Low)).

Cattle use: Because of poor spring plant growth, the cattle were not turned out until April 9. A summary of cattle use by the one rancher's cattle who utilized the pastures during 1979 follows:

On April 9 and 10, 161 cows, calves, and bulls were turned into L3 (Table 2.b.1 and 2.b.2). The cattle spread over the area and utilized the forage during the early part of the season. During the later part of the cattle's stay in L3, they tended to stay in the northern part of the pasture and the southern areas received little use.

The cattle were moved to H3 between June 13 and June 22. The cattle did not spread out over H3 very well and by late August some cattle were losing weight. On September 12, the rancher was notified that he would have to move his cattle off the Boise Front by October 1. Most of the cattle were removed by October 2, with the remaining removed by October 28. The cattle were moved off the Boise Front early, because the extremely dry conditions and heavy grasshopper infestation were limiting winter feed for big game. Calves were weighed as they were taken off H3, so most of the calves were weighed over a 12-day period, which was about a month earlier than normal (Table 2.b.3). Calf rate of weight gain was about the same as 1978.

Table 2.b.1.--Grazing schedule and type of management for Boise Front pastures.

Year	Pasture			
	High or Low, 1	High or Low, 2	High or Low, 3	High or Low, 4
1978	C Early Rest (until seed ripe) (Graze Picket Pin 4/1-5/8)	A Graze Season Long	D Rest Season Long (seedling establishment)	B Rest Season Long (for plant vigor)
1979	D Rest Season Long (seedling establishment)	B Rest Season Long	A Graze Season Long	C Early Rest (until seed ripe)
1980	A Graze Season Long	C Early Rest (until seed ripe)	B Rest Season Long (for plant vigor)	D Rest Season Long (seedling establishment)
1981 (1977)	B Rest Season Long (for plant vigor)	D Rest Season Long (seedling establishment)	C Early Rest (until seed ripe)	A Graze Season Long

Table 2.b.2.--Dates cattle grazed Boise Front pastures during 1979.

Pasture	Cattle Grazing Dates	Time for ^{1/} Cattle to move Between Pastures
Low 3	April 9-June 12	
High 3 ^{2/}	June 13-October 1	June 13-22

^{1/}Dates indicate opening and closing of gates

^{2/}The cattle moved out of H3 starting September 20, most were out by October 2, and all were out by October 28.

Table 2.b.3.--Rate of gain of randomly selected cattle during 1979^{1/}

	AVERAGE		RANGE	
	Rate of Gain	Pounds Gained	Rate of Gain	Pounds Gained
	<u>Pounds Per Day</u>		<u>Pounds Per Day</u>	
Calves	.94	170	.42-1.34	80-235
Heifers	.89	160	.42-1.34	80-235
Steers	.98	177	.46-1.26	85-230

^{1/}Spring weighing-March 29, 1979

Fall weighing dates varied because the calves were weighed as they came off H3.

Sheep use: One band of 2100 ewes and lambs used the Boise Front during the spring and fall of 1979. They entered H1 on May 14 and then moved through L2, H2, and H3 before leaving the Front on June 2. During the fall, they entered H4 about November 5, then moved through H3, L3, L2, and left L1 on December 1.

Deer use: The Boise Front rotation grazing pastures serve as a winter deer range where bitterbrush is the main browse plant. There were 1404 deer between Warm Springs Creek and Deadwood Creek, and 547 in L4 at

the time of the January 1979 count. Utilization information was collected during the spring and summer of 1979, the results of which are listed in Table 2.b.4. Of the available leaders, 31 percent or more were used on all pastures. Twig length utilization was least in L1, as was the case in 1978. The greatest utilization was in L2.

Utilization information was obtained in L3 on June 20 to determine cattle use. The cattle utilized only 6 percent of the bitterbrush while they were in the pasture, which was from April 9 through June 12.

Table 2.b.4.--Bitterbrush utilization on the Boise Front pastures during 1978-1979.

Pasture	Percent of Available Twigs Showing Hits	Percent of Total Utilization ^{1/}
MARCH		
Low 1	31	19 ^{2/}
Low 2	83	53 ^{3/}
Low 3	71	43 ^{2/}
Low 4	73	44 ^{2/}
JUNE 20		
Low 3	10	6 ^{4/}

^{1/}Use of annual growth equals percent of twigs taken times percent of available leaders used.

^{2/}Utilization by deer and sheep

^{3/}Utilization by deer, cattle, and sheep

^{4/}Utilization by cattle from April 9 through June 12, 1979.

Frequency percentage, overstory, and basal cover: Species frequency and cover were collected at the rotation grazing study sites in L1, L2, and L3 pastures. The presence of any plant species occurring within an 18-in² quadrat was identified. One hundred quadrat placements were used at each of the exclosures and rotation grazed treatments at each site. Species frequency percentage is listed in Table 2.b.5. This was the third year frequency data were obtained and no noticeable difference of species composition between treatments has been observed.

Table 2.b.5.--Frequency percentage of plant species within enclosure and on adjacent rotation grazing pastures.

	Pasture					
	3321		3227		3222	
	Low 1		Low 2		Low 2	
	Exclosure	Rotation	(Maynard Gulch) 1/		(Pond Spring) 1/	
		Grazed	Exclosure	Rotation	Exclosure	Rotation
				Grazed		Grazed
<i>Agropyron species</i>						1
<i>Agropyron intermedium</i>		1	1	2		1
<i>Agropyron spicatum</i>		2				
<i>Artichida longiseta</i>	11	100	78	78	99	11
<i>Bromus tectorum</i>	97	100	19	10		45
<i>Festuca arida</i>	52	31				62
<i>Festuca megaleura</i>	5	5		2	27	43
<i>Poa sandbergii</i>	95	96	98	97		88
<i>Sitanion hystrix</i>	90	87	89	66	16	98
<i>Taeniatherum caput-medusae</i>				1	99	83
<i>Achillea millefolium lanulosa</i>						97
<i>Agoseris species</i>						1
<i>Anemone nemorosa</i>	61	74	65	36	5	3
<i>Anemone dimorpha</i>	1			3		30
<i>Asparagus parshii</i>	17	25	10	15		6
<i>Balsamorhiza sagittata</i>	1	3	5	1		3
<i>Belamcandula scabra</i>	58	59	55	38	6	5
<i>Calochortus macrocarpus</i>	2	2	3	3		2
<i>Cirsium canaliculatus</i>	8	8				1
<i>Crepis occidentalis</i>	39	23	3	6	11	49
<i>Cryptantha species</i>						3
<i>Eriogonum fasciculatum</i>	95	96	92	89	10	23
<i>Erodium cicutarium</i>	9	25	27	29	46	87
<i>Eriogonum</i>						18
<i>Eriogonum ucinum</i>	33	34	6	15		19
<i>Helianthus species</i>	13	12	2	3	25	6
<i>Holosteum umbellatum</i>	95	94	91	81	10	20
<i>Lagophylla hamosissima</i>					25	72
<i>Lactuca serriola</i>	43	37	36	11	95	41
<i>Lepidium species</i>	96	95	93	99	56	48
<i>Lomatium nudicaule</i>				2		93
<i>Lomatium triternatum platycarpum</i>			2	8		
<i>Lupinus species</i>				2		2
<i>Microseris species</i>			1			6
<i>Myosotis species</i>	2	5	28	58		35
<i>Phlox species</i>	9	8	7	16		44
<i>Plectritis macrocarpa</i>				3		1
<i>Polygonum majus</i>			1			19
<i>Thysanocarpus curvipes</i>					2	24
<i>Tragopogon dubius</i>						5
<i>Forb</i>						2
<i>Artemisia tridentata</i>		1		1		1
<i>Chrysothamnus nauseosus albicaulis</i>	2					2
						1

1/ Grazed 1979.

Overstory measurements were collected in 1979 with a summary of the 1977 through 1979 surveys listed in Table 2.b.6. There were no noticeable differences between the treatments.

Percent basal cover for the years 1977 through 1979 is listed in Table 2.b.7. The cover differences between the exclosure and grazed areas are small except for litter and bare ground in L3, where in 1979 there was more litter and less bare ground in the grazed area. This difference may have been due to cattle grazing. L3 was grazed during 1979 and there was no grazing on the other two pastures.

Survival of marked bottlebrush squirreltail (*Sitanion hystrix*) seedlings was noted at the four exclosure study sites, both on the grazed areas and in the exclosures. The seedlings were marked in early spring and checked the last week of August. In L3, 8 of the 10 and 9 of the 10 seedlings survived in the grazed and in the exclosure, respectively. The one plant marked in the L2 (Spring) site survived. In L2 (Maynard Gulch), 5 out of 10 survived in the exclosure and 4 out of 9 in the grazed area. The lowest survival rate was in L1, where 1 out of 10 survived in the exclosure and 3 out of 10 survived in the grazed area.

Table 2.b.6.--Percent overstory for different cover components at four rotation pasture sites in 1977, 1978, and 1979.

	Pasture											
	Low 1			Low 2 (Maynard Gulch)			Low 2 (Pond Spring)			Low 3		
	1977	1978	1979	1977	1978	1979	1977	1978	1979	1977	1978	1979
VEGETATION TOTAL												
Exclosure	26	48	25	41	43	41	47	59	39	37	43	30
Rotation Grazed	33	58	22	33	41	38	58	76	61	52	46	36
LITTER												
Exclosure	24	21	27	19	6	19	48	34	55	27	14	17
Rotation Grazed	14	3	25	18	5	18	36	21	34	17	18	32
ROCK												
Exclosure	11	14	6	2	3	5	0	1	1	5	6	4
Rotation Grazed	15	11	9	3	2	3	2	1	1	6	4	2
BARE GROUND												
Exclosure	39	17	42	38	48	35	5	6	4	31	37	49
Rotation Grazed	38	28	44	46	52	41	4	3	4	25	32	30

Table 2.b.7.--Percent basal cover for different components at four rotation pasture sites in 1977, 1978, and 1979.

	Pasture											
	Low 1			Low 2 (Maynard Gulch)			Low 2 (Pond Spring)			Low 3		
	1977	1978	1979	1977	1978	1979	1977	1978	1979	1977	1978	1979
VEGETATION TOTAL												
Exclosure	17	7	11	32	24	18	15	22	24	18	15	14
Rotation Grazed	28	19	6	20	27	18	8	28	10	9	12	13
LITTER												
Exclosure	32	28	30	23	12	26	78	64	67	36	28	25
Rotation Grazed	19	8	32	24	10	27	85	65	82	59	40	44
ROCK												
Exclosure	11	33	7	3	4	7	2	2	1	5	8	4
Rotation Grazed	15	17	11	4	4	4	2	1	1	6	6	3
BARE GROUND												
Exclosure	40	32	52	42	60	49	5	12	8	41	49	57
Rotation Grazed	38	56	51	52	59	51	5	6	7	26	42	40

3. RUNOFF

Personnel Involved

C. W. Johnson,
Research Hydraulic Engineer

Plan programs and procedures;
design and construct facilities
for runoff studies; perform
analyses and summarize results.

D. L. Brakensiek,
Research Hydraulic Engineer

Streamflow and infiltration
modeling.

C. L. Hanson,
Agricultural Engineer

Test various components in run-
off models most applicable to
rangelands.

R. L. Engleman,
Mathematician

Perform data compilation and
assist in analyses.

J. P. Smith, R. P. Morris,
and V. M. Aaron,
Hydrologic Technicians

Data collection, compilation, and
analyses.

M. D. Burgess,
Electronic Technician

Designs, constructs, and services
electronic sensors and radio
telemetry systems.

D. C. Robertson,
Hydrologic Technician

Snowmelt runoff.

a. Reynolds Creek

(Reynolds Creek site locations are shown on Introduction, Figure 1.)

A PROBABILITY ANALYSIS OF REYNOLDS CREEK WATERSHED RUNOFF

The maximum floods of record for the Reynolds Creek Watersheds are shown on Figure 3.a.1 plotted against drainage area. Maximum floods from other rangeland watersheds in Southwest Idaho also are shown for comparative purposes. The peak flow events used in Figure 3.a.1 were compiled from USGS Water Resources Investigations, 7-73 (Thomas, et al., 1973), the USGS peak flow file, and from the Reynolds Creek SEA records. The flow data are limited to watersheds of less than 500 mi². Table 3.a.1 lists the stations and dates of occurrence of the peak discharges. All of the floods above 1000 csm and the majority of the floods above 100 csm were from intense thunderstorms. All flows greater than 100 csm were from drainage areas of less than 40 mi² and all flows greater than 200 csm were from drainage areas of less than 5 mi². Some of the most severe flooding of record occurred on August 20, 1959, when a severe thunderstorm hit the Boise foothills after they had been denuded by a range fire on August 3, 1959.

The flooding of December 23, 1964, is considered to be some of the most severe of record in the Western United States. The severity of flooding in Southwest Idaho varied from one area to another. Within the Reynolds Creek basin, runoff rates ranged from 98 csm on Macks Creek (12.3 mi²) to 43 csm at the Outlet weir (90.2 mi²). The flood of December 23, 1964 provides important information in accessing the frequency of annual maximum flows. The recurrence interval of the 1964 flood was estimated to be 60 years for the Reynolds Creek basin with the exception of Macks Creek, which was estimated to be 85 years. These are subjective estimates based upon ranchers recollections of other major events, precipitation records, comparative analyses with other drainages, and an analysis of the maximum potential flood hazard.

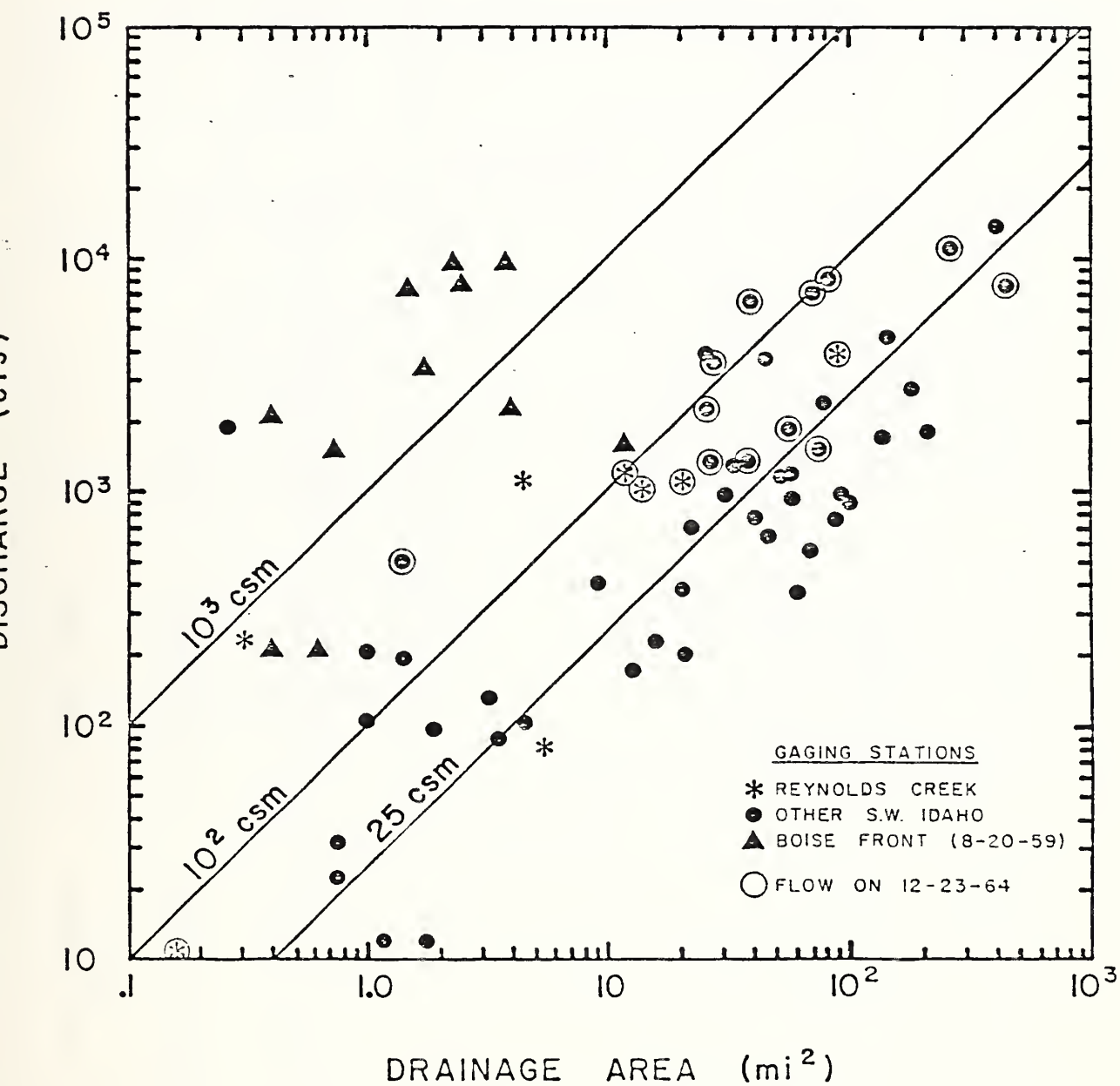


Figure 3.a.1.--Maximum discharges in relation to drainage area

Table 3.a.1.--Maximum discharges at selected sites.

No.	Stream Name	Drainage area (sq. mi.)	Date	Dis- charge (cfs)	Dis- charge (csm)
BIG WOOD RIVER BASIN					
13135500	Big Wood River near Ketchum	137	05-24-67	1,690	12
13136500	Warm Springs Creek at Guyer Hot Springs	a96	05-21-58	961	10
M13142850	Big Wood River Tributary	15.8	02-12-62	226	14
M13145800	Thorn Creek	a46	02-11-62	647	14
M13145900	Preacher Creek	a26	12-23-64	2,210	85
M13147100	Dry Creek	a84	12-22-64c	8,050	96
13150500	Silver Creek	a88	02-04-63	757	9
CLOVER CREEK BASIN					
M13153800	Clover Creek	71.2	12-23-64	7,000	98
M13153900	Calf Creek	39.4	12-23-64	6,400	162
13154000	Clover Creek near Bliss	140	02-13-70	4,500	32
M13154400	Clover Creek	265	12-23-64	10,100	38
TRIBUTARIES TO SNAKE RIVER BETWEEN CLOVER CREEK AND BRUNEAU RIVER					
13155000	King Hill Creek near King Hill	78.9	02-01-63	2,320	29
M13155100	Rosevear Gulch	55.9	08-31-63	1,160	21
13155200	Burns Gulch near Glenns Ferry	0.76	02-01-63	22	29
13155300	Little Canyon Cr. at Stout Crossing near Glenns Ferry	14.2	12-23-64	500	35
13155400	Little Canyon Creek at Berry Ranch	26.9	12-23-64	1,330	49
13156500	Bennett Creek near Bennett	21.3	04-02-43	204	10
13157000	Bennett Creek near Hamnett	68.6	02-16-13	550	8
M13161050	Squaw Creek	61.5	09-16-61	368	6
BRUNEAU RIVER BASIN					
13161200	Seventy-six Creek near Charleston, NV	3.52	05-00-75b	89	25
13161300	Meadow Creek near Rowland, NV	57.8	06-04-63	940	16
13162200	Jarbridge River at Jarbridge, NV	22.6	06-00-70b	700	31
13162400	Buck Creek near Jarbridge, NV	20.2	06-00-71b	380	19
13163200	Sheep Creek	a180	06-05-63	2,760	15
M13168380	Hot Creek	42.2	08-13-68	772	18
M13169250	Bruneau River Tributary	.63	08-13-68	208	330
13169500	Big Jacks Creek	253	01-21-43	2,100	8
13170000	Little Jacks Creek	100	01-21-43	908	9
13170100	Sugar Creek Tributary near Grasmere, ID	4.50	06-10-69	105	23
M13170200	Sugar Creek	33.6	08-13-68	1,300	39
TRIBUTARIES TO SNAKE RIVER BETWEEN BRUNEAU RIVER AND BOISE RIVER					
M13172100	Browns Creek	a31	08-13-68	967	31
M13172300	Sinker Creek	a74	12-23-64	1,500	20
M13172600	Rabbit Creek	a45	06-19-62	3,640	81
M13172620	Rabbit Creek Tributary	4.3	06-19-62	1,140	265
M13172640	West Rabbit Creek	27.0	06-20-62	3,740	139
M1317	Rabbit Creek Tributary	0.27	06-11-77	1,900	7,037
M13172700	Nancy Gulch	a4	06-19-62	375	94
68036068	Reynolds Outlet	90.2	12-23-64	3,850	43
68046017	Salmon Creek	13.9	12-23-64	1,007	73
68046034	Macks Creek	12.3	12-23-64	1,200	98
68116083	Reynolds Creek at Tollgate	21.0	12-23-64	1,100	52
68135017	Dobson Creek	5.44	03-29-74	82	15
68166074	Reynolds Mountain West	0.20	12-23-64	9.3	47
68166076	Reynolds Mountain East	0.16	12-23-64	10.7	67
68	Reynolds Tributary	4.5	06-11-77	1,125	250
13172800	Little Squaw Creek Tributary near Marsing, Idaho	1.81	01-31-63	93	51
13172930	Spring Cr. Tributary near Rockville, OR	0.76	01-21-72	30	40
13173500	Sucker Creek	413	02-01-63	13,300	32

Table 3.a.1.--Maximum discharges at selected sites--Cont'd.

No.	Stream Name	Drainage area (sq. mi.)	Date	Dis- charge (cfs)	Dis- charge (csm)
OWYHEE RIVER BASIN					
13174500	Owyhee River near Gold Creek, NV	209	05-05-22	1,810	9
13177885	Pole Creek Tributary near McDermitt, NV	1.00	01-21-72	105	105
13177895	Antelope Cr. Tributary near McDermitt, NV	3.20	06-30-70	132	41
13178000	Jordan Creek	440	12-24-64	7,530	17
BOISE RIVER BASIN					
M13184950	Sheep Creek	28.2	12-23-64	3,590	127
13187000	Fall Creek	55.3	04-27-52	1,150	21
M13192400	Rattlesnake Creek	37.8	12-23-64	1,320	35
M13192900	Willow Creek	57.0	12-23-64	1,820	32
13198000	Elk Creek	13.1	08-17-41	172	13
M13201400	Sheep Creek	0.40	08-20-59	210	525
M13203520	Highland Valley Gulch	.39	08-20-59	2,100	5,385
M13203530	Highland Valley Gulch	1.69	08-20-59	3,370	1,994
M13203600	Maynard Gulch	2.25	08-20-59	9,540	4,240
M13203750	Squaw Creek	1.47	08-20-59	7,320	4,980
M13203800	Warm Springs Creek	3.84	08-20-59	9,390	2,445
M13204600	Orchard Gulch	.73	08-20-59	1,500	2,055
M13204700	Picket Pin Creek	2.50	08-20-59	7,720	3,088
M13204800	Cottonwood Gulch	12.0	08-20-59	1,580	132
M13204900	Curlew Gulch	3.95	08-20-59	2,300	582
M13205650	Ussery Street Gulch	.06	06-21-67	90	1,500
M13205700	Stuart Gulch	9.04	01-29-65	412	46
M13205750	Polecat Gulch	1.01	06-21-67	210	203
M13205800	Boise River Tributary	.25	06-21-67	9.8	39
M13205850	Pierce Gulch	1.18	06-21-67	12	10
M13206100	Seaman Gulch	1.76	06-21-67	12	7
M13207650	Goose Creek	1.42	05-20-68	195	137

a Approximately

b Exact date unknown

c Date may have been 12-24-64

The annual flood series were fit to the Log Pearson Type III (LP3) distribution following the guidelines developed by the Water Resources Council, WRC, (1977). The results were quite unsatisfactory. Table 3.a.2 shows the annual flood series statistics in both real and log space, and the final WRC estimate when historical information is incorporated into the record. The systematic sequence is positively skewed in real space and negatively skewed in log space. The negative skewness is exaggerated with the incorporation of the historical information. One of the drawbacks of the LP3 distribution is that its shape is influenced throughout its range by outliers. Furthermore, where the skew is negative in log space, flows distributed as LP3 are bounded above. The WRC method of parameter estimation also does not preserve the moments of the observed values and, therefore, reduces in importance the high outliers, (Bobee, 1975). For these reasons, the 500-year flood, after fitting the LP3, was less than the highest flow of record for several of the series. Forcing the skew to zero, which is the special case of the log normal distribution, improved the fit some, but still did not produce consistent results with the historical record. The annual series were also fit to the two parameter log normal distribution and the Gumbel Type I external distribution. The two distributions were less sensitive to outliers, but, again, produced results that were not completely satisfactory.

Table 3.a.2.--Statistics of annual flood series.

STATION	NATURAL FLOWS				LOG ₁₀ TRANSFORM					
	SYSTEMATIC RECORD				SYSTEMATIC RECORD			WRC ESTIMATES WITH HISTORICAL DATA		
	N	\bar{X}	S	G	\bar{X}	S	G	\bar{X}	S	G
68036068	17	831	982	1.83	2.685	0.471	0.08	2.644	0.428	-0.02
68046017	15	180	249	2.41	1.990	0.503	-0.05	1.935	0.441	-0.39
68046084	15	201	295	2.51	2.011	0.524	0.08	1.948	0.450	-0.24
68116083	15	257	251	2.43	2.266	0.394	-0.79	2.225	0.347	-1.52
68166076	17	4.65	2.54	0.74	0.596	0.278	-0.70	0.576	0.261	-0.92

NOTE: N is the number of years of record

\bar{X} is the mean

S is the standard deviation

G is the coefficient of skew

The final frequency curves shown in Figures 3.a.2 and 3.a.3 and the results shown in Table 3.a.3 are from a graphical solution, which incorporates historical data into the final frequency curve. The historical data were assigned a return period of $n+1$ years, where it was known that the historical flow was the largest in the past n years. The systematic record plotting positions were adjusted to the longer period, assuming that the systematic record represented the distribution of frequencies during the longer historical period (Benson, 1950). The Q_{100}/Q_2 ratio, which gives some indication of the slope of the frequency curve, ranges from 2.8 at Reynolds Mountain (68166076) where the annual flood is generally from snowmelt, to 12.9 on Salmon Creek (68046017) where the annual flood may be from snowmelt, thunderstorm activity, or rain on snow and frozen soil. The frequency curve for the Tollgate drainage (68116083) is a good example of a composite curve of floods originating from different sources. The shape of the upper part of the frequency curve is determined by winter rainfall events, while the lower part of the curve is determined by the snowmelt events. Any analytical solution would require that the snowmelt and rainfall events be analyzed separately.

Table 3.a.3.--Discharges at selected recurrence intervals of 2, 5, 10, 20, 50, and 100 years.

Discharge in cubic feet per second						
	<u>Q_2</u>	<u>Q_5</u>	<u>Q_{10}</u>	<u>Q_{20}</u>	<u>Q_{50}</u>	<u>Q_{100}</u>
68036068	480	1130	1730	2440	3560	4480
68046017	96	240	393	585	910	1240
68046084	104	257	410	600	930	1245
68116083	195	310	425	605	1000	1380
68166076	4.18	6.00	7.28	8.58	10.3	11.6

Discharge in cubic feet per second per square mile						
	<u>Q_2</u>	<u>Q_5</u>	<u>Q_{10}</u>	<u>Q_{20}</u>	<u>Q_{50}</u>	<u>Q_{100}</u>
68036068	5	13	19	27	40	50
68046017	7	17	28	42	65	89
68046084	9	21	33	49	76	101
68116083	9	15	20	29	48	66
68166076	27	38	47	55	66	74

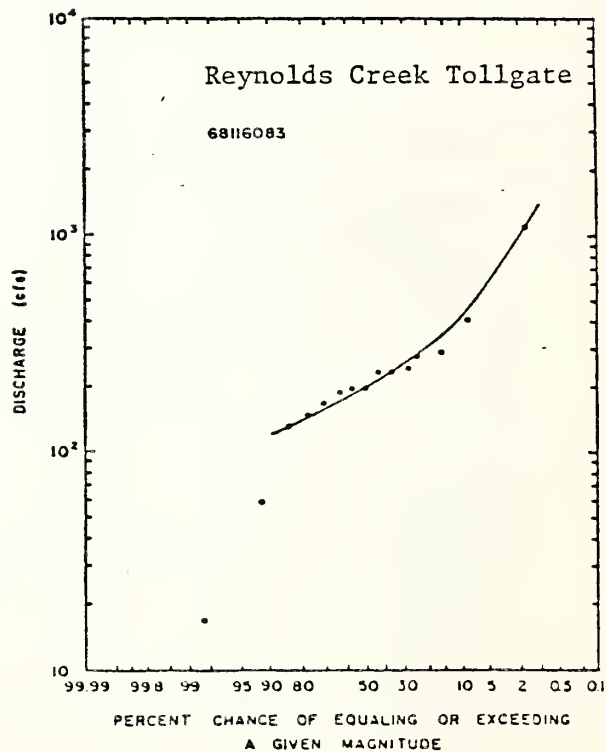
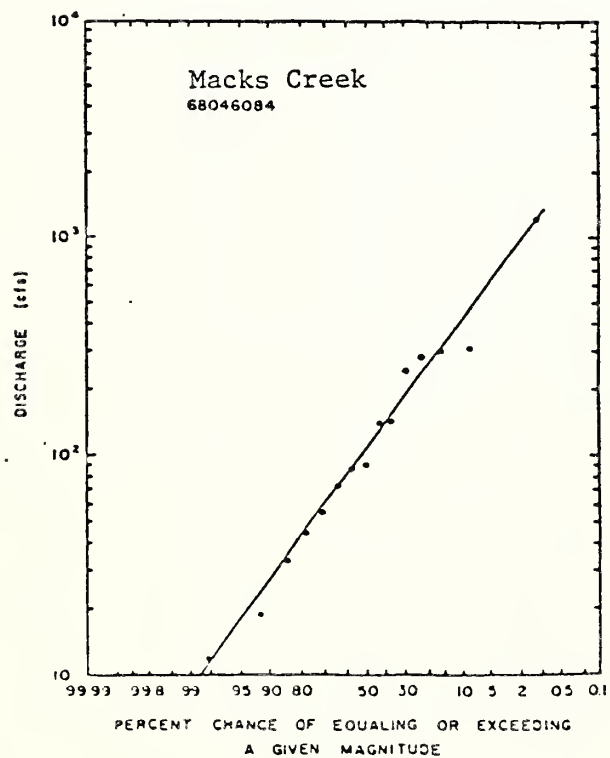
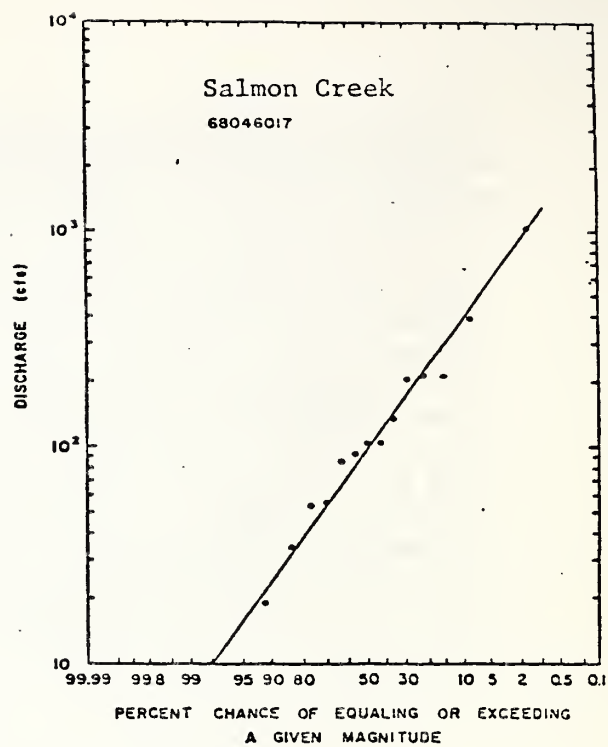
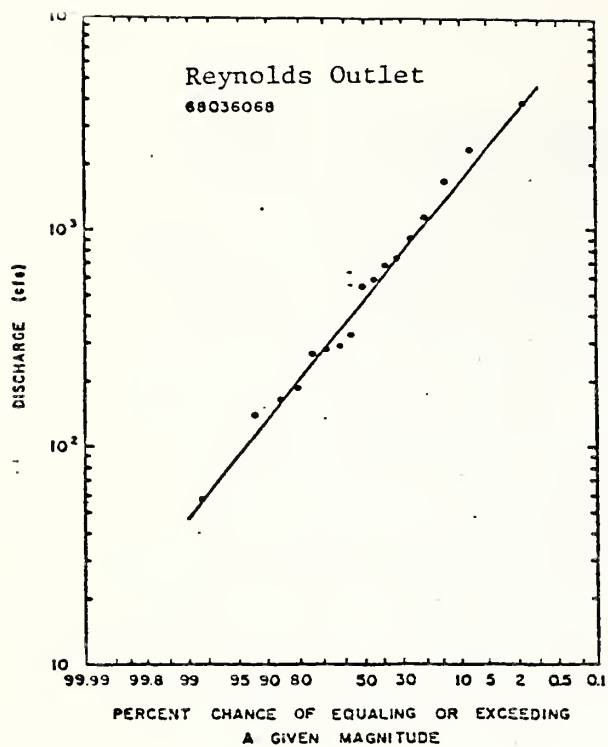
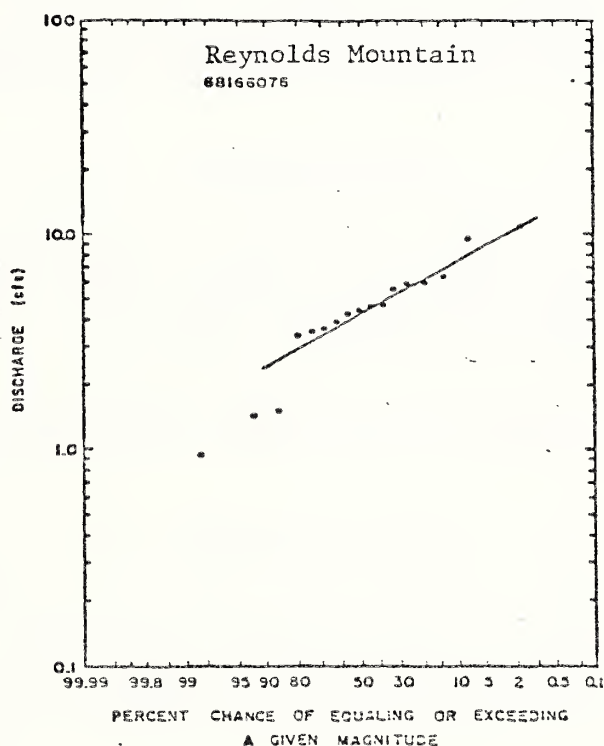


Figure 3.a.2.--Flood Frequency curves, Reynolds Creek Watershed Stations.

The diverse conditions found at Reynolds Creek point out the problems encountered when attempting to follow uniform guidelines for determining flood frequencies by an analytical technique. Skew coefficients vary with the mix of different types of floods, and are difficult to regionalize with the short history for small drainages. Blind use of any statistical method for determining flood frequencies would be discouraged. Uniform procedures do not mean that the results will be uniformly correct.



WINTER FLOOD

The third highest flood of record from the Reynolds Creek Watershed occurred at 2:15 p.m., January 11, 1979. A rapid increase in temperature to about 50°F at the Weather Station, deeply frozen soil from near record December and January cold temperatures, snowmelt, and rain combined to produce 1662 ft³/sec peak streamflow at the Outlet weir. Runoff was mainly from areas less than 5500 feet elevation where the shallow snow almost completely melted and 1-2 inches of rain and snow fell on January 10-11. Above 5500 feet elevation temperatures were generally near freezing, snow was much deeper, and little runoff occurred. Conditions causing this flood were similar to December and January events in 1963, 1969, 1970, 1971 and 1972.

MICROWATERSHEDS

Flats: Winter rain, snowmelt, and frozen soil caused runoff at this station on January 11 and February 7, 1979. However, frozen floats and other problems prevented accurate data collection. Also, some slight runoff occurred from 1/2 inch of intense rain, August 9, 1979.

Nancy Gulch: The winter storms in January and February caused some runoff at this station, but again ice and other problems prevented accurate data collection.

SOURCE WATERSHEDS

Lower Sheep: Runoff from this 33-acre watershed in the 1979 water year was 0.34 inch, slightly greater than the 13-year mean at this station, Table 3.a.4. Precipitation was 9.96 inches, about 73 percent of the 17-year mean. The peak runoff rate was 1.33 ft³/sec on January 11, 1979, the third highest of record. About 60 percent of the yearly runoff was from rain and snowmelt on January 11.

Reynolds Mountain East: Runoff from this 100-acre watershed above 6600 feet elevation was 15.15 inches, about 75 percent of the 17-year mean, Table 3.a.4. The peak runoff rate was 3.52 ft³/sec on May 15 from snowmelt, about 76 percent of the 4.65 ft³/sec mean. Water year precipitation was 32.38 inches, about 78 percent of the mean. Summer streamflow was very low because of below normal June and July precipitation.

Reynolds Mountain West: Runoff from this 126-acre watershed was 11.65 inches, about 72 percent of the mean, 16.19 inches, Table 3.a.4. The peak runoff rate was 3.99 ft³/sec, 67 percent of the mean.

Table 3.a.4.--Water year precipitation, runoff, and peak streamflow, source watersheds, Reynolds Creek Experimental Watershed.

Water Year	Lower Sheep Watershed				Reynolds Mountain East Watershed				Reynolds Mountain West Watershed			
	Precipitation	Runoff	Peak Streamflow	Date of Peak	Precipitation	Runoff	Peak Streamflow	Date of Peak	Precipitation	Runoff	Peak Streamflow	Date of Peak
	inches	inches	ft ³ /sec		inches	inches	ft ³ /sec		inches	inches	ft ³ /sec	
1963	16.98	----- ^{1/}	----	----	37.82	11.11	4.16	Apr. 29	----- ^{2/}	----- ^{3/}	----	----
1964	13.55	----	----	----	40.89	21.02	3.60	May 16	----	----	----	----
1965	20.86	----	----	----	66.10	34.87	10.70	Dec. 23	----	25.00	9.29	Dec. 23
1966	6.81	----	----	----	28.36	9.86	1.43	May 5	----	7.39	1.87	Apr. 8
1967	18.73	0.34	1.41	Jan. 21	50.45	21.01	5.44	May 22	----	17.18	5.10	May 22
1968	11.30	0.02	0.08	Feb. 18	31.97	6.72	1.48	Aug. 10	----	6.31	1.97	Feb. 23
1969	14.12	0.52	0.49	Jan. 20	37.45	22.43	3.88	May 12	37.37	17.26	4.20	May 10
1970	14.24	0.02	0.05	Jan. 27	39.60	20.06	5.89	May 17	37.95	20.24	12.33	May 17
1971	17.68	0.31	0.20	Mar. 12	57.96	31.06	5.77	May 4	45.75	21.41	10.24	May 4
1972	13.82	0.91	2.08	Jan. 22	50.51	33.52	6.26	June 6	45.98	29.56	6.31	May 14
1973	12.20	0.01	0.02	Apr. 17	31.01	13.24	3.31	May 8	28.40	10.02	5.35	Apr. 27
1974	10.28	0.26	0.38	Mar. 15	45.54	26.64	4.33	May 7	38.67	19.77	5.61	May 7
1975	14.89	0.73	0.90	Feb. 13	51.57	27.93	9.27	June 2	42.83	21.24	14.28	June 2
1976	14.46	0.55	0.31	Mar. 17	42.51	22.35	4.59	May 13	-----	16.38	4.09	May 2
1977	8.27	0	0	----	21.11	3.44	0.93	Apr. 16	-----	2.31	0.72	Apr. 16
1978	15.13	0.14	0.09	Apr. 27	43.82	23.12	4.50	May 14	-----	17.07	3.52	May 14
1979	9.96	0.34	1.33	Jan. 11	32.38	15.15	3.52	May 15	-----	11.65	3.99	May 4
MEAN	13.72	0.32	0.56	----	41.71	20.21	4.65	----	-----	16.19	5.92	----

^{1/} Runoff station record began in 1966.

^{2/} Precipitation record began in 1968 and terminated in 1975.

^{3/} Runoff station record began in 1964.

TRIBUTARY WATERSHEDS

Salmon Creek: Runoff from this 8900-acre watershed was 2.25 inches in 1979, 72 percent of the 15-year mean, Table 3.a.5. The peak runoff rate was 380 ft³/sec on January 11, 1979, over twice the mean value and the second highest of record. Water year precipitation was 17.57 inches, 86 percent of the 17-year mean.

Macks Creek: Runoff from this 7846-acre watershed was 2.10 inches, 85 percent of the 14-year mean, Table 3.a.5. The peak runoff rate was 300 ft³/sec on January 11, 1979, compared with a mean of 130 ft³/sec. Water year precipitation was 16.31 inches, 83 percent of the 11-year mean, 19.73 inches.

Dobson Creek: Runoff from this 3482-acre watershed was 9.18 inches, 81 percent of the 7-year mean, Table 3.a.5. The peak runoff rate was 31 ft³/sec on May 16, compared with a mean of 49 ft³/sec. Precipitation was 26.91 inches, 74 percent of the 17-year mean.

MAIN STEM WATERSHEDS

Reynolds Creek Outlet: Runoff from this 57,700-acre watershed was 2.06 inches, 69 percent of the 17-year mean, Table 3.a.6. The peak runoff rate was 1662 ft³/sec on January 11, 1979, over twice the mean yearly peak and third highest of record. This peak was the result of sudden warm temperatures and rain following near record cold temperatures, which froze the soil and caused snow accumulation. Flood runoff was from areas generally below 5500 feet elevation. Yearly precipitation was 14.51 inches, 79 percent of the 17-year mean. June, July, and August runoff was about 1/3 to 1/2 of normal, because of low precipitation in those months, Table 3.a.7.

Reynolds Creek Tollgate: Runoff from this 13,453-acre watershed was 6.78 inches, 73 percent of the 14-year mean, Table 3.a.6. The peak runoff rate was 121 ft³/sec on January 11, 1979, about 62 percent of the mean. Precipitation was 20.16 inches, 72 percent of the 17-year mean, 28.15 inches. Runoff was below normal in all months except May, Table 3.a.7., because of the low precipitation and snow accumulation.

EVALUATION OF THE SCS RUNOFF EQUATION

Evaluations are limited to Reynolds Creek. The unavailability of a completed soils map and the absence of growing season runoff events preclude an evaluation of the Boise Front.

Table 3.a.5.--Water year precipitation runoff, and peak streamflow, Tributary Watersheds,
Reynolds Creek Experimental Watershed.

Water Year	Salmon Creek				Macks Creek				Dobson Creek			
	Precipi- tation	Runoff	Peak Streamflow	inches	Precipi- tation	Runoff	Peak Streamflow	inches	Precipi- tation	Runoff	Peak Streamflow	inches
	inches	inches	ft ³ /sec		inches	inches	ft ³ /sec		inches	inches	ft ³ /sec	
1963	22.63	----	----	----	----	----	----	----	36.12	----	----	----
1964	19.90	----	----	----	----	----	----	----	32.48	----	----	----
1965	33.51	9.65	1007	----	----	----	1200	----	40.89	----	----	----
1966	10.27	1.05	10	----	----	0.61	12	----	23.78	----	----	----
1967	22.77	2.24	85	----	----	1.54	90	----	39.56	----	----	----
1968	14.73	0.77	34	----	----	0.49	44	----	32.54	----	----	----
1969	19.36	3.14	209	19.90	19.90	2.93	307	----	40.61	----	----	----
1970	24.96	3.07	210	19.29	19.29	1.92	241	----	41.67	----	----	----
1971	24.35	3.61	132	23.65	23.65	3.79	281	----	52.68	----	----	----
1972	22.74	5.50	201	23.43	23.43	4.84	138	----	42.29	----	----	----
1973	17.35	2.14	55	15.93	15.93	1.76	54	7.62	28.93	7.62	49	49
1974	16.80	3.31	53	15.54	15.54	3.72	71	17.42	38.94	17.42	82	82
1975	20.43	3.54	92	22.68	22.68	4.79	142	16.78	41.85	16.78	65	65
1976	22.81	2.38	19	21.02	21.02	2.67	33	12.97	38.37	12.97	43	43
1977	12.53	0.62	103	14.67	14.67	0.43	19	2.86	20.62	2.86	9	9
1978	23.42	3.41	102	24.61	24.61	3.01	86	13.00	36.30	13.00	66	66
1979	17.57	2.25	380	16.31	16.31	2.10	300	9.18	26.91	9.18	31	31
MEAN	20.36	3.11	179	19.73	19.73	2.47	130	11.40	36.15	11.40	49	49

Table 3.a.6.--Water year precipitation, runoff, and peak streamflow for main stem watersheds.

Water Year	Reynolds Creek Outlet				Reynolds Creek at Tollgate			
	Precipitation ^{1/} inches	Runoff inches	Peak Streamflow ft ³ /sec	Date of Peak	Precipitation ^{2/} inches	Runoff inches	Peak Streamflow ft ³ /sec	Date of Peak
1963	25.03	1.85	2331	Jan. 31	31.07	-----	-----	-----
1964	15.25	2.45	188	Jan. 25	24.25	-----	-----	-----
1965	26.83	7.05	3850	Dec. 23	38.93	-----	1100 ^{3/}	-----
1966	9.05	0.76	59	Apr. 1	13.79	3.55	59	Apr. 1
1967	19.68	2.19	265	June 7	28.10	9.09	288	June 7
1968	14.20	0.61	327	Feb. 21	21.51	3.08	186	Feb. 21
1969	16.85	3.60	900	Jan. 21	29.11	11.47	405	Jan. 21
1970	20.13	2.70	729	Jan. 27	31.35	9.64	240	Jan. 27
1971	24.96	4.78	540	Jan. 18	41.89	14.98	196	May 6
1972	22.13	6.07	678	Mar. 2	38.12	16.45	271	Mar. 2
1973	16.19	1.85	166	Apr. 17	25.18	6.00	147	Apr. 17
1974	17.14	4.37	291	Mar. 29	29.53	12.75	195	Mar. 29
1975	19.57	4.12	281	Mar. 25	31.18	13.31	231	June 2
1976	20.34	2.84	140	Apr. 5	29.90	10.05	130	May 10
1977	11.41	0.35	1119	June 11	15.49	1.51	17	Apr. 8
1978	19.64	3.29	589	Apr. 26	28.98	11.32	230	Apr. 26
1979	14.51	2.06	1662	Jan. 11	20.16	6.78	121	Jan. 11
MEAN	18.28	3.00	830	-----	28.15	9.28	194	-----

^{1/} Rain gage No. 116X91.^{2/} Rain gage No. 155X07.^{3/} Estimated peak flow.

Table 3.a.7.--Water year runoff in 1979 and the mean of record by months.

Month	Reynolds Creek Outlet Runoff		Reynolds Creek Tollgate Runoff	
	1979	1963-1978	1979	1966-1978
	-----inches-----			
October	.019	0.026	.077	0.085
November	.034	0.049	.088	0.141
December	.060	0.178	.104	0.235
January	.330	0.413	.274	0.615
February	.309	0.271	.321	0.421
March	.387	0.491	.697	1.070
April	.178	0.594	1.041	1.824
May	.596	0.636	3.267	3.254
June	.102	0.311	.765	1.482
July	.024	0.050	.101	0.259
August	.010	0.023	.029	0.051
September	.014	0.014	.011	0.038
Total	2.063	3.056	6.775	9.475

Application of the SCS runoff equation requires the determination of a "potential maximum retention" parameter, S. The initial abstraction term, I_a , is eliminated from the equation by assuming that it is 0.2 of S, thus resulting in the SCS runoff equation

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \quad (1)$$

where

Q = 24 hour or daily runoff
P = 24 hour or daily rainfall
S = potential maximum retention

A curve number, CN, is used rather than S, where S and CN have been related by the expression

$$S = (1000/CN) - 10$$

The curve number for rangelands is determined from SCS tables (1971). Required inputs for determining the appropriate curve number, CN, from these tables are the Hydrologic Soil Group (HSG), Land Use-Treatment practice,

Hydrologic Conditions and Antecedent Moisture Conditions, AMC, (I-Lowest runoff condition, II-Average condition, or III-Highest runoff condition).

The procedures reported herein are directed at reducing the subjectivity in the HSG and AMC determination. They have been developed from continuing research on applying the Green and Ampt infiltration equation to the runoff estimation problem.

As reported last year (Interim Report No. 9, April 1979), published soil moisture characteristic data (volumetric soil water retained at specific soil capillary pressure value) would be utilized to estimate the Green and Ampt parameters for a range of soil textures. The data sources were publications by Rawls, et al., (1976) and Holton, et al., (1968). The first stage of this effort fitted the Brooks and Corey equation to the data. This equation relates effective soil saturations, S_e , to capillary pressure, Ψ , i.e.,

$$S_e = (\Psi_b / \Psi)^\lambda \quad (2)$$

where

Ψ_b = Bubbling pressure, cm

Ψ = Capillary pressure, cm

λ = Pore size distribution index

and

$$S_e = (\theta - \theta_r) / (\theta_s - \theta_r)$$

where

θ = Volumetric soil water content

θ_r = Residual soil water content

θ_s = Volumetric soil water content at saturation (taken as total porosity, ϕ)

The parameters estimated from each data set are θ_r , Ψ_b , and λ . Total porosity, ϕ , is calculated from the bulk density determined at 0.3 bar tension (306 cm). The mean values for these parameters over a range of textures are presented in Table 3.a.8.

In Table 3.a.9 are the Green and Ampt infiltration equation parameters. This equation and its parameters are as follows:

$$f = K \left(1 + \frac{n \Psi_f}{F} \right)$$

where

f = Infiltration rate

F = Infiltration amount

K - Conductivity

Ψ_f = Wetting front capillary pressure

n = Available soil porosity = ϕ_e - Antecedent Soil Moisture

Table 3.a.8.--Arithmetic Mean Values of the Brooks and Corey Parameters^{1/}.

SOIL TEXTURE CLASS	λ	Ψ_b	ϕ	θ_h
	---	cm	---	---
Sandy	0.52	13.15	0.37	0.02
Loamy Sand	0.47	14.85	0.39	0.02
Sandy Loam	0.35	19.85	0.42	0.03
Loam	0.29	23.79	0.44	0.04
Silty Loam	0.19	32.61	0.48	0.04
Sandy Clay Loam	0.35	19.85	0.42	0.06
Clay Loam	0.25	27.19	0.46	0.07
Silty Clay Loam	0.17	35.49	0.49	0.07
Sandy Clay	0.33	21.34	0.43	0.08
Silty Clay	0.16	37.25	0.49	0.09
Clay	0.21	30.69	0.47	0.11

$$\frac{1}{S_e} = \frac{\theta - \theta_h}{\phi - \theta_h} = (\Psi_e/\Psi)^\lambda$$

Table 3.a.9.--Arithmetic Mean Values of the Green and Ampt Parameters^{1/}.

SOIL TEXTURE	Ψ_f	$K^{2/}$	ϕ_e
	cm	cm/hr	----
Sand	8.56	11.78	0.354
Loamy Sand	9.91	2.99	0.363
Sandy Loam	14.09	1.09	0.390
Loam	17.65	0.340	0.397
Silty Loam	25.68	0.648	0.441
Sandy Clay Loam	14.09	0.153	0.331
Clay Loam	20.62	0.097	0.407
Silty Clay Loam	28.46	0.097	0.404
Sandy Clay	15.38	0.064	0.347
Silty Clay	30.17	0.051	0.402
Clay	23.87	0.034	0.362

^{1/} $f = K (1 + n\Psi_f/F)$, where $n = \phi_e$ - Antecedent Soil Moisture.

^{2/} Green and Ampt $K = 1/2 \{ \text{EXP} (\ln KS) \} \times 3600$, cm/hr.

The K-values were determined from saturated conductivity values compiled in an unpublished study by Strait, et al., (1978). The Green and Ampt parameter K corresponds to the minimum infiltration rate referred to by Musgrave (1955) in his original definition of the Hydrologic Grouping of Soils, i.e., A, B, C, or D. Table 3.a.10, using his rate limits and the Green and Ampt K-values, classifies soil testure classes into Hydrologic Soil Groups. The soil testure K or minimum infiltration rate values can be used to classify a soil profile. This will be illustrated in the following sections.

Table 3.a.10.--Hydrologic Soil Group Classified by Soil Texture.

HYDROLOGIC SOIL GROUP	SOIL TEXTURE	MINIMUM INFILTRATION RATE
		----in/hr----
?	Sand	4.64
?	Loamy Sand	1.18
A(0.3-.45 in/hr)	Sandy Loam	0.43
B(0.15-.30 in/hr)	Silt Loam	0.26
C(0.05-.15 in/hr)	Loam	0.13
C	Sandy Clay Loam	0.06
D(0.0-0.05 in/hr)	Clay Loam	0.04
D	Silty Clay Loam	0.04
D	Sandy Clay	0.03
D	Silty Clay	0.02
D	Clay	0.01

WATERSHED TEST

To illustrate the use of the Brooks and Corey and Green and Ampt parameters, the SCS runoff procedure is first applied to a Reynolds Creek research watershed. Table 3.a.11 presents pertinent soil data for the 205-acre Summit watershed. The Hydrologic Soil Groups for each soil association, given in column 5 of Table 3.a.11, were estimated as follows: First the depth of soil wetted is estimated. Using the K-values (Table 3.a.10) for each layer, the mean K (harmonic mean) is calculated for the wetted depth. Knowing the soil profile minimum infiltration rate, the Hydrologic Soil Group (HSG) can be determined from Table 3.a.10.

Using the hydrologic data in Tables 3.a.12 and 3.a.13 a wetted depth was approximated. Since runoff amounts were very small, total infiltration

is nearly the rainfall amount. Referring to Table 3.a.8, the total porosity for a loam, sandy loam, sandy clay loam, and a clay loam soil can all be approximated as 0.44. For the rainfall observed amounts, the maximum wetted depth will not exceed 4.5 inches. For example, the August 17, 1968 event had an available soil porosity of $(0.44 - 0.22) = 0.22$ inches of water per inch of soil. The wetted depth is than approximately $(0.99 / 0.22) = 4.5$ inches. A minimum infiltration rate for the Bakeoven-Reywat-Babbington soil associations calculated as a harmonic mean over the wetted depth of 4.5 inches is as follows:

$$K = \frac{4.5}{(3/0.13 + 1.5/.04)}$$

$$K = 0.07 \text{ in/hr}$$

From Table 3.a.10 this corresponds to a Hydrologic Soil Group (HSG) of C. The other soil associations were wetted in only the surface depth, thus their HSG's are read directly from Table 3.a.10 for the appropriate soil texture and are recorded in column 5, Table 3.a.11. Note that these are much different from the SCS soil survey HSG classification (column 6, Table 3.a.11).

The Antecedent Moisture Condition, I, II, or III, is here related to soil water storage values that are calculated from the Brooks and Corey equation. In standard SCS procedures, the AMC is based on 5-day antecedent rainfall, see Table 4.2, Chapter 4, NEH-4.

Table 3.a.11.--Summit Watershed, Reynolds Creek, Idaho.

Soil Association	Surface Depth and Texture	Subsurface Depth and Texture	Percent of Area	Est. HSG	SCS ^{1/} HSG
		3-7"			
Bakeoven-Reywat-Babbington	0-3" Loam	Gravelly Loam-Gravelly Clay Loam	65	C	D
	0-6"	6-10"			
Farrot-Castlevalle-Brownlee	Rocky Sandy Loam	Coarse-Sandy Clay Loam	12	A	D
	0-9"	9-15"			
Nannyton-Larimer-Ackmen	Loam	Gravelly Heavy Loam	23	C	B

^{1/} Stephenson, G. R. (editor). 1977.

Table 3.a.12.--Hydrologic data for Summit Watershed and Estimated SCS Runoff Equation Factors.

Date	Rainfall Inches	Measured Antecedent Soil Water	AMC1/ class	Soil Association Runoff curve number		
				BRB	FCB	NLA
6-1-67	0.80	0.21	II	86	68	86
8-9-68	0.77	0.10-0.16	I	71	49	71
8-14-68	1.04	0.21	II	86	68	86
8-17-68	0.99	0.21-0.23	II	86	68	86
6-19-69	1.29	0.10-0.17	I	71	49	71

1/ AMC classes related to the following water content ranges for a loam soil: AMC I = less than 0.2
AMC II = 0.21-0.3
AMC III = 0.31-0.44

Actual soil water measurements were available on the Bakeoven-Reywat-Babbington, and the Nannyton-Larimer-Ackmen soil associations. Both were classed as a loam (C-soil). The parameters for the loam texture in Table 3.a.8 were used in equation (2) to calculate the soil water volumes retained at so-called field capacity and wilting point.

Saturation, θ_s = 0.44 in/in (0 bar)

Field Capacity, θ_{fc} = 0.22 in/in (1.3 bar)

Wilting Point, θ_{wp} = 0.16 in/in (15 bar)

Table 3.a.13.--Runoff Computations, Summit watershed, Soil Association Runoff, and Watershed Runoff.

Date	Calculated Runoff for Soil Association			Calculated Watershed Runoff	Measured Watershed Runoff
	BRB inches	FCB inches	NLA inches	inches	inches
6-1-67	0.11	0	0.11	0.10	0.002
8-9-68	0	0	0	0.0	0.001
8-14-68	0.22	0.002	0.22	0.19	0.044
8-17-68	0.19	0.0	0.19	0.17	0.039
6-19-69	0.05	0	0.05	0.04	0.068
TOTAL				0.50	0.154

Antecedent soil moisture content classes I, II, and III were defined as moisture content intervals covering the above values of wilting point, field capacity, and saturation, respectively, i.e., I-less than 0.17, II-0.17-0.3; and III-0.31-0.44.

Vegetative cover plus litter on the watershed was determined to vary from 0 to 25 percent. From Table 8.1 (NEH-4, Chapter 8) this corresponds to a Hydrologic Condition of Poor. In Table 9.1 (SCS, NEH-4, Chapter 9) for Range, no Mechanical Treatment, and Poor Hydrologic Conditions, the runoff curve numbers for an A and C Soil with an AMC II condition are 68 and 86, respectively.

Table 3.a.12 gives the hydrologic data for runoff-producing rainstorms in the years 1967, 1968, and 1969. The curve numbers are corrected for the actual AMC. In Table 3.a.13, the runoff amounts are calculated for each soil association for the daily rainfall amounts. Measured watershed runoff is also given.

Table 3.a.14 gives the runoff amounts calculated with the curve numbers estimated in this study, compared with those estimated by the SCS soil survey. An additional comparison is made with runoff amounts calculated by Hanson (1979) in his study of the USDA Hydrograph Laboratory model (Holton, et al., 1975). The small amounts of runoff involved on this semiarid watershed do not permit a conclusive comparison. However, it does indicate that the HSG estimation procedure developed here does improve upon the SCS soil survey estimate.

Table 3.a.14.--Comparisons of Runoff amounts, Summit Watershed, for the HSG from this study and from the SCS soil survey.

RUNOFF				
Date	Measured	EST HSG	SCS HSG	USDAL MODEL
	inches	inches	inches	inches
6-1-67	0.002	0.10	0.14	0.000
8-9-68	0.001	0.00	0.01	0.000
8-14-68	0.044	0.19	0.26	0.000
8-17-68	0.039	0.17	0.23	0.000
6-19-69	0.068	0.04	0.10	0.035
TOTAL	0.154	0.50	0.74	0.035

INFILTROMETER TESTS

Infiltrometer tests on Reynolds Creek involving much larger amounts of rainfall and runoff and actual soil moisture measurements are utilized to further test the proposed HSG and AMC prediction procedures. In the summer of 1972 infiltration tests were conducted at five Reynolds Creek Watershed sites. The equipment and techniques used in these tests are described by Brakensiek, et al., (1979). Each site represents one soil type, i.e., Nannyton Loam (2 sites), Babbington Loam (2 sites), and Searla gravelly Loam (1 site). Soils information for each site is given in Tables 3.a.15, 3.a.16, and 3.a.17. In general, the data at each site consisted of an application rate, amount, and duration, runoff rates and amounts, infiltration rates and amounts, soil water (volume basis) before and after each test and bulk density by depths, and test site percent cover.

Table 3.a.10 was used to estimate the Hydrologic Soil Group (HSG) from the calculated minimum infiltration rate for the measured wetted depth of soil. Table 8.1 was used to estimate the Hydrologic condition and (SCS, NEH-4) Table 9.1 was used to determine the appropriate curve number (CN). Table 10.1 (SCS, NEH-4) was used when necessary to modify the curve number for an antecedent moisture condition (AMC) other than II.

The following tables present the soils data for each test site.

Table 3.a.15.--Nannyton Loam

Layer	Texture	Min. Infil. Rate	Layer HSG ^{1/}	Profile Depth	Profile HSG
inches		in/hr		inches	
0-2	Gravelly Sandy Loam	1.18	A	2	A
2-5	Gritty Loam	.13	C	5	B ^{2/}
5-8	Gravelly Loam	.26	B	8	B
8-12	Light Clay Loam	.04	D	12	C
12-15	Gravelly Clay Loam	.06	C	15	C
15-19	Gritty Loam	.13	C	19	C
19-26	Sandy Loam	.43	A	26	C

^{1/} Hydrologic Soil Group

^{2/} $K = 5 / (3 / .13 + 2 / 1.18) = 0.20$
 Table 3 HSG-B, 0.15-30"/hr

Table 3.a.16.--Babbington Loam

Layer	Texture	Min. Infil. Rate	Layer HSG	Profile Depth	Profile HSG
inches		in/hr		inches	
0-3	Loam	.13	C	3	C
3-6	Slightly Gravelly Heavy Loam	.13	C	6	C
6-12	Clay Loam	.04	D	12	C
12-20	Slightly Gravelly Heavy Clay Loam	.04	D	20	C
20-28	Gravelly Clay Loam	.06	C	28	C

Table 3.a.17.--Searla Gravelly Loam

Layer	Texture	Min. Infil. Rate	Layer HSG	Profile Depth	Profile HSG
inches		in/hr		inches	
0-3	Gravelly Loam	.26	B	3	B
3-9	Gravelly Loam	.26	B	9	B
9-15	Light Clay Loam	.04	D	15	C
15-24	Gravelly Clay Loam	.06	C	24	C

A HSG is estimated for a soil profile from the harmonic mean of the layered minimum infiltration rates, using the soil texture values in Table 3.a.10. The soil depth corresponds to the wetted depth. The calculated harmonic mean is then compared with class intervals, column 1, Table 3.a.10, and the appropriated HSG is selected. A number of the soil texture descriptions included gravel as a modifier. In these cases, the HSG was raised one letter, i.e., a Gravelly Loam was raised from a C to a B, Table 3.a.10. At present, we have no data to judge the true affect of the gravel content on the minimum infiltration rate. Calculated HSG values for soil profile depths are given in Table 3.a.15, 3.a.16, and 3.a.17.

The Brooks and Corey equation, utilizing the parameters in Table 3.a.8, was used to calculate Field Capacity (FC) and Wilting Point (WP) for each soil texture. The AMC classes were estimated using these values. For the comparisons, the standard SCS procedure, utilizing the 5-day antecedent rainfall, was also used. Runoff amounts were calculated with the SCS runoff equation using both the procedures of this study to estimate HSG and AMC values and also standard SCS procedures. Hydrologic data for each site are given in Table 3.a.18.

Table 3.a.19 presents data input for calculating runoff. Table 3.a.20 compares the calculated runoff by the procedures of this study and standard SCS procedures. These tests again indicate that the proposed procedure for estimating the Hydrologic Soil Group (HSG) and basing the I, II, and III antecedent moisture condition on calculated soil moisture storage values, gives an improved runoff estimate. However, the proposed procedures do require additional information, i.e., depth of soil that will be wetted, antecedent soil moisture content, and a soil profile description.

Table 3.a.18.--Infiltrometer Site Data.

Site	Water Applied in	Initial Abstraction in	Runoff in	Wetted Depth in	Antecedent Soil Water in/in	Ground Cover Veg. + Litter Percent	Antecedent 5-day Water in
Nannyton-1	4.50	0.40	2.03	21	0.26	18	4.00
Nannyton-2	4.53	0.20	3.60	18	0.27	18	2.80
Babbington-1	5.46	0.42	3.01	24	0.15	75	1.23
Babbington-2	4.50	0.27	1.62	21	0.30	75	4.84
Searla-1	9.00	0.25	4.35	21	0.32	56	3.15

Note: All sites are non-contoured range

Table 3.a.19.--Derived Site Data.

Site	Hydrologic Condition	Standard SCS Procedures				Proposed Methodologies			
		AMC	HSG	CN	Q in	AMC	HSG	CN	Q in
Nannyton-1	Poor	III	B	90	3.40	II(FC=0.24)	C	86	3.00
Nannyton-2	Poor	III	B	90	3.42	II(FC=0.24)	C	86	3.03
Babbington-1	Fair	I	B	50	0.89	I(WP=0.15)	C	63	1.81
Babbington-2	Fair	III	B	84	2.82	II(FC=0.27)	C	79	2.38
Searla-1	Fair	III	B	84	7.06	II(Sat=0.44 FC=0.23)	C	79	6.44

Table 3.a.20.--Infiltrometer Test Summary

Site	Water Applied	Meas. Runoff	Proposed Procedures			SCS STD		
			AMC	HSG	Q	AMC	HSG	Q
Nannyton-1	4.50	2.03	II	C	3.00	III	B	3.40
Nannyton-2	4.53	3.60	II	C	3.03	III	B	3.42
Babbington-1	5.46	3.01	I	C	1.81	I	B	0.89
Babbington-2	4.50	1.62	II	C	2.38	III	B	2.82
Searla-1	9.00	4.35	II	C	6.44	III	B	7.06
Totals		14.61			16.66			17.59

The wetted depth can be easily approximated by making an initial estimate of the runoff and calculating infiltration as rainfall minus runoff. Utilizing the soil total porosity reduced by initial soil water content, the depth of soil required to store the infiltrated water can be calculated. For example, the wetted depth of the Searla gravelly loam (Table 3.a.17) might have been estimated to be 9 inches. The HSG is then a B soil. Using an AMC II condition for a Fair range Hydrologic Condition, the calculated runoff would be 5.2 inches and infiltration would be 3.8 inches. With a field capacity moisture content and the total porosity for a loam soil (Table 3.a.8, $\phi = 0.44$), the available porosity is 0.21 in/in. Hence, 18 inches of soil would be required to hold the 3.8 inches of calculated infiltration. Clearly, the wetted depth is in the range of a C soil (Table 3.a.17).

An antecedent soil moisture condition would need to be estimated by a soil water accounting procedure using antecedent rainfall events. It appeared in this evaluation that, except for very dry conditions, i.e., no antecedent 5-day rainfall, the use of rainfall amounts per se will generally overestimate the AMC.

In Table 3.a.21 is shown the individual influences of the HSG and AMC determination on the runoff estimate. The runoff amount was calculated for the possible combinations of the proposed procedure and the standard SCS procedures. At least for the Reynolds Creek tests, the SCS procedure for AMC results in an overestimate of runoff, and the SCS estimate of the HSG results in an underestimate of runoff.

On the basis of this evaluation, it appears that an improved Hydrologic Soil Group designation can be estimated from the soil profile soil texture descriptions. Also, the proposed procedure is more objective, and soil water holding capacities can be calculated and used for quantifying the AMC designation. Using antecedent rainfall amounts for characterizing the AMC will generally lead to an overestimate of runoff.

A remaining need in the SCS runoff procedure is to develop a better estimate of the Hydrologic Conditions (HC). A change of one class in the HC can change the runoff estimate more than all other factors combined. For example, on the Summit watershed, if the rangeland Hydrologic conditions had been Fair instead of Poor, all other factors remaining the same, the runoff estimation would have been as shown in Table 3.a.22.

Table 3.a.21.--Infiltrometer Test Comparisons^{1/}

Site	Meas. RO	Calculated RO			
		Est-HSG Est-AMC	Est-HSG SCS-AMC	SCS-HSG Est-AMC	SCS-HSG SCS-AMC
NL-1	2.03	3.00	3.50	2.40	3.40
NL-2	3.60	3.03	4.00	2.40	3.42
BL-1	3.01	1.81	1.80	0.90	0.89
BL-2	1.62	2.38	3.40	1.60	2.82
SGL-1	4.35	6.44	7.80	5.20	7.06
Total	14.61	16.66	20.50	12.50	17.59

EST - Estimation procedures from this study

SCS - SCS standard procedure

Table 3.a.22.--Effect of the Hydrologic Condition on Summit Watershed runoff estimation by the SCS runoff equation.

Date	Measured Runoff inches	H. C. = Poor Runoff inches	H. C. = Fair Runoff inches
6-1-67	0.002	0.10	0.022
8-9-68	0.001	0.00	0.000
8-14-68	0.044	0.19	0.073
8-17-68	0.039	0.17	0.060
6-19-69	0.068	0.04	0.002
Total	0.154	0.50	0.157

Future infiltration studies should focus on relating soil surface cover factors to infiltration and runoff amounts.

REFERENCES: SECTION 3.a.

- Benson, M. A. 1950. Use of historical data in flood-frequency analyses. Amer. Geophys. Union Trans. V. 31, p 419-424.
- Bobee, B. 1975. The Log Pearson Type III distribution and its application in hydrology. Water Resources Research, 11(5): 681-689.
- Brakensiek, D. L., et al. 1979. Application of an infiltrometer system for describing infiltration into soils. Trans. ASAE 22(2): 320-325.
- Hanson, C. L. 1979. Simulation of arid rangeland watershed hydrology with the USDAHL-74 model. Trans. ASAE 22(2): 304-309.
- Holton, H. N., C. B. England, G. P. Lawless, and G. A. Schumaker, 1968. Moisture-tension data for selected soil on experimental watersheds. ARS 41-144, USDA-ARS, 609 pp.
- Holton, H. N., G. J. Stiltner, W. H. Henson, and N. C. Lopez. 1975. USDAHL-74 revised model of watershed hydrology. USDA Tech. Bull. No. 1518, 99 pp.
- Musgrave, G. W. 1955. How much of the rain enters the soil? In: Year Book of Agriculture, p 151-159.
- Rawls, W., P. Yates, and L. Asmussen. 1976. Calibration of selected infiltration equations for the Georgia Coastal Plain, ARS-S-113, USDA-ARS, 110 pp.
- SCS National Engineering Handbook, Section 4, Hydrology, Supt. of Doc. USGPO, Washington, D. C., 1971, Chapters 4, 8, 9, and 10, Tables 4.2, 8.1, 9.1, and 10.1, respectively.
- Stephenson, G. R. (Editor). 1977. Soil-geology-vegetation inventories for Reynolds Creek Watershed. University of Idaho, Agricultural Experiment Station, Misc. Pub. 42.
- Strait, S., K. Saxton, R. I. Papendick. 1978. Unpublished release. Pressure and hydraulic conductivity curves for various soil textures.
- Thomas, C. A., W. A. Harenberg, J. M. Anderson. 1973. Magnitude and frequency of floods in small drainage basins in Idaho. USGS, Water Resources Investigations. 61 pp.
- Water Resources Council. 1977. Guidelines for determining flood flow frequencies. U.S. Water Resources Council Bull. No. 17A of the Hydrology Committee, Washington, D. C.

b. Boise Front

(Boise Front Watershed runoff station locations are shown in Introduction, Figure 2.)

BOISE FRONT WATERSHEDS

Upper Maynard Gulch: Runoff from this 725-acre watershed was 3.01 inches in the 1979 water year, Table 3.b.1. The peak runoff rate was $4.19 \text{ ft}^3/\text{sec}$ on February 13, 1979. The peak from a similar event on January 11, 1979 was $3.88 \text{ ft}^3/\text{sec}$. Streamflow was only about $0.01 \text{ ft}^3/\text{sec}$ during much of June, July, and August because of low precipitation. Water year precipitation ranged from 13.75 inches at 3800 feet elevation near the runoff-measuring station to 19.66 inches at 5450 feet elevation near the headwaters.

Lower Maynard Gulch: Runoff from this 644-acre watershed below the Upper Maynard runoff station was only 0.24 inch when runoff from the upper watershed was subtracted, Table 3.b.1. Obviously, this stream is an important recharge area for groundwater near Boise. Peak streamflow was $17.55 \text{ ft}^3/\text{sec}$ on January 11, 1979. All months except January, February, and March showed more streamflow at the upper runoff station than at the lower station. Precipitation ranged from 10.94 inches at 2880 feet elevation near the watershed outlet to 13.75 inches at 3800 feet elevation, the upper extreme of the lower watershed. Boise precipitation was 88 percent of normal.

Camp Creek: Runoff from this 717-acre watershed was 1.50 inches in 1979, Table 3.b.1. The peak runoff rates were $6.02 \text{ ft}^3/\text{sec}$ on February 11, and $5.69 \text{ ft}^3/\text{sec}$ on January 11, 1979, from rain and snowmelt on frozen soil. The stream was completely dry in July, August, and September.

Highland Creek: Runoff from the 988-acre watershed was 2.75 inches in 1979, Table 3.b.1. The peak runoff rates were $2.78 \text{ ft}^3/\text{sec}$ on February 14 and $2.17 \text{ ft}^3/\text{sec}$ on January 11, 1979. Minimum streamflow was about $0.01 \text{ ft}^3/\text{sec}$ during the summer dry season.

TABLE 3.b.1.--1979 water year runoff by months from Boise Front watersheds.

Month	Watershed			
	Maynard Gulch		Creek	Highland Creek
	Upper	Lower ^{1/}		
	-----inches-----			
Oct.	0.086	- 0.042	0.015	0.095
Nov.	0.116	- 0.048	0.106	0.116
Dec.	0.145	- 0.034	0.080	0.140
Jan.	0.202	0.321	0.163	0.217
Feb.	0.595	0.272	0.519	0.290
Mar.	0.912	0.070	0.317	0.867
Apr.	0.457	- 0.077	0.177	0.527
May	0.401	- 0.135	0.106	0.309
June	0.063	- 0.041	0.014	0.088
July	0.003	- 0.003	0	0.017
Aug.	0.013	- 0.015	0	0.035
Sep.	0.019	- 0.021	0	0.045
Year Total	3.012	0.247	1.497	2.746

^{1/}Minus values show streamflow losses in the channel between the runoff measuring station. The Lower Maynard runoff measuring station is about 1½ miles downstream from the Upper Maynard station.

4. EROSION AND SEDIMENT

Personnel Involved

C. W. Johnson,
Research Hydraulic Engineer

Plan programs and procedures;
design and construct facilities
for sediment studies; perform
analyses and summarize results.

G. R. Stephenson,
Geologist

Determine geologic and geomorphic
parameters related to sediment
yield.

C. L. Hanson,
Agricultural Engineer

Test various components in sedi-
ment models most applicable to
rangelands.

R. L. Engleman,
Mathematician

Perform data compilation and
assist in analyses.

J. P. Smith,
Hydrologic Technician

Data collection, compilation,
and analyses.

J. H. Harris,
Scientific Aid
(U. of Idaho Cooperator)

Data collection and sediment
analyses.

M. D. Burgess,
Electronic Technician

Designs, constructs, and ser-
vices electronic sensors and
radio telemetry systems.

a. Reynolds Creek

(Reynolds Creek Experimental Watershed station locations are shown in the Introduction, Figure 1.)

USLE SOIL LOSS AND PSIAC SEDIMENT YIELD

The following report summarizes results of a study of the USLE and PSIAC procedures by Clifton W. Johnson, SEA-AR, and Karl A. Gebhardt, BLM, presented at the Pacific Northwest Region Meeting of the American Society of Agricultural Engineers, Boise, Idaho, October 3-5, 1979.

Soil erosion and sediment yield are major concerns to land owners and managers responsible for maintaining productivity and land resource values. Since the Bureau of Land Management (BLM), U. S. Department of Interior, is responsible for administration of about 72 million ha of land in the conterminous United States, Clawson and Held (1957), the department must address the complex environmental impacts of grazing, land and energy development, and alternative land uses. The legal requirements of Environmental Impact Statements, EIS, on areas of proposed development have shown the need for accurate and quantitative erosion and sediment yield methods for predicting results of land disturbance and management.

Comparative analysis is a common technique in EIS preparation, because it shows the effects of alternative actions in relation to present conditions or some recognized standard. Generally, there is a lack of on-site field data, because of the large expense required for information collection (Richerson and Johnston, 1975); therefore, appropriate methods and data must often be extrapolated to the area under consideration. This study shows an application of the Universal Soil Loss Equation, Wischmeier and Smith (1978), and the Pacific Southwest Inter-Agency Committee, PSIAC (1968), sediment yield evaluation procedure on southwest Idaho rangelands. Predicted soil loss by the USLE and sediment yields by the PSIAC procedure are compared with measured yields from areas within the Reynolds Creek Experimental Watershed in southwest Idaho.

Application of the PSIAC procedure was an extension of the study reported by Shown (1970), with additional relationships and equations developed to utilize available watershed data. Contributions to the study by B. Leifeste (1978) and R. D. Clark^{1/} are acknowledged. Objectives in this study were to test the sensitivity of the USLE and PSIAC procedure to changes in grazing and vegetative cover, to compare measured and predicted sediment yields, and to show how the methods can be used in predicting the effects of rangeland management practices on cover and soil loss.

^{1/} Personal communication, 1977.

Although actual soil loss measurements were not made on watershed slopes, the procedures provide a useful comparison to show relative effects of various treatments and management practices.

PROCEDURES

The soil loss rate on each watershed area classified by slope, rainfall, soil, and cover was estimated by the USLE,

$$A = RKLSCP \quad (1)$$

where

A = Computed soil loss per unit area in tons per acre per year

R = Rainfall and runoff factor, including runoff from snowmelt

K = Soil erodibility factor

L = Slope-length factor

S = Slope-steepness factor

C = Cover and management factor

P = Support practice factor and the value was set equal to 1.0 in this study

The R values for Reynolds Creek sagebrush rangeland sites were determined by using Reynolds Creek Experimental Watershed precipitation data and procedures developed by McCool, et al., (1976) for the Pacific Northwest with snowmelt and soil thaw problems. The K values were determined using soils data from a report by Stephenson (1977) and a soil erodibility list for Idaho (Soil Conservation Service, 1974). The LS values were based on photo interpretations, field surveys, and graphical relationships developed by McCool, et al., (1976). The C values were determined by using range vegetation canopy and ground cover surveys^{2/}, and a routine developed by Wischmeier (1975).

^{2/} Data was obtained at representative sites by step-point transects using procedures described in BLM Manual 7313.

Sediment yields were computed for Reynolds Creek Watersheds by a modified PSIAC procedure using the equation

$$SY = 0.253e^{0.036 \text{ Rating}} \quad (2)$$

where, SY is sediment yield in t/ha (metric tonnes/ha), assuming a sediment volume-weight of 1,360 kg/m³, e is the base of natural logarithms, and Rating is the sum of PSIAC factors, see Figure 4.a.1. Equation (2) was derived from data of Leifeste adjusted to eliminate minus values; thus changing the rating but not the procedure. The PSIAC Rating values were defined by the equation

$$\text{Rating} = Y_1 + Y_2 + Y_3 + Y_4 + Y_5 + Y_6 + Y_7 + Y_8 + Y_9 \quad (3)$$

where Y₁ is the surface geology factor, Y₂ is the soils factor, Y₃ is the climate factor, Y₄ is the runoff factor, Y₅ is the topography factor, Y₆ is the ground cover factor, Y₇ is the land use factor, Y₈ is the upland erosion factor, and Y₉ is the channel erosion and sediment transport factor. These factors and the independent variables used to determine the relationships are shown in Figures 4.a.2 through 4.a.10, where X₁, Figure 4.a.2, is a geologic erosion index based on rock type, hardness, fracturing, and weathering, (hard massive rock was assigned an index of one and marine shale, mudstone, or siltstone was assigned an index of 10), the geology-erosion index relationship in this study was interpreted from the Reynolds Creek geology report, McIntyre (1972); X₂, Figure 4.a.3, is the USLE soil erodibility factor; X₃, Figure 4.a.4, is the 2-year 6-hour precipitation value for each area, as determined from a Reynolds Creek Watershed precipitation analysis; X₄, Figure 4.a.5, is the sum of annual peak streamflow (m³/sec/km² x 50) and annual watershed runoff (mm x 0.03); X₅, Figure 4.a.6, is the percent slope; X₆, Figure 4.a.7, is the percent bare ground; X₇, Figure 4.a.8, is the percent aerial ground cover; X₈, Figure 4.a.9, is the soil surface factor, SSF^{3/}, evaluated by field survey; and X₉, Figure 4.a.10, is the SSF^{3/}, gully rating.

^{3/} The SSF was determined using procedures described in BLM Manual 7317.

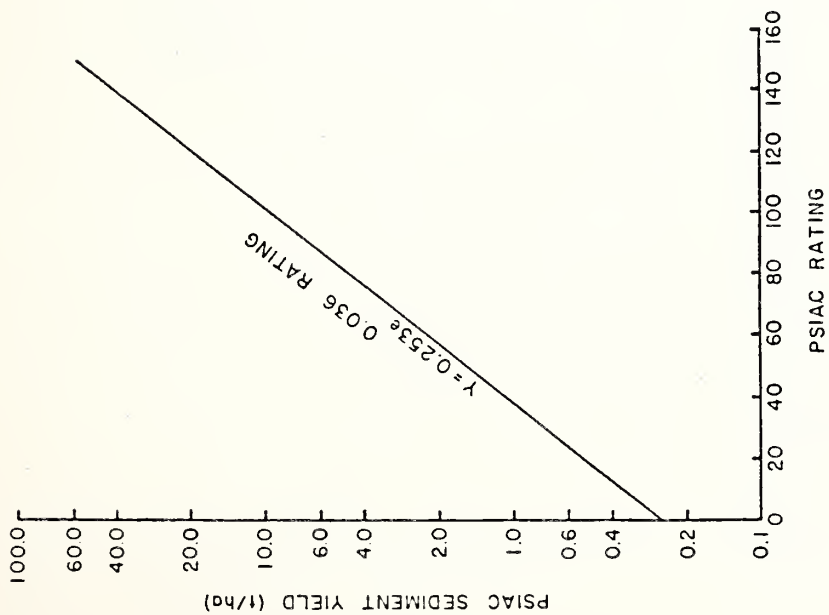


FIGURE 4.a.1.1.--THE RELATIONSHIP BETWEEN PSIAC RATING AND SEDIMENT YIELD DERIVED FROM DATA OF LEIFESTE.

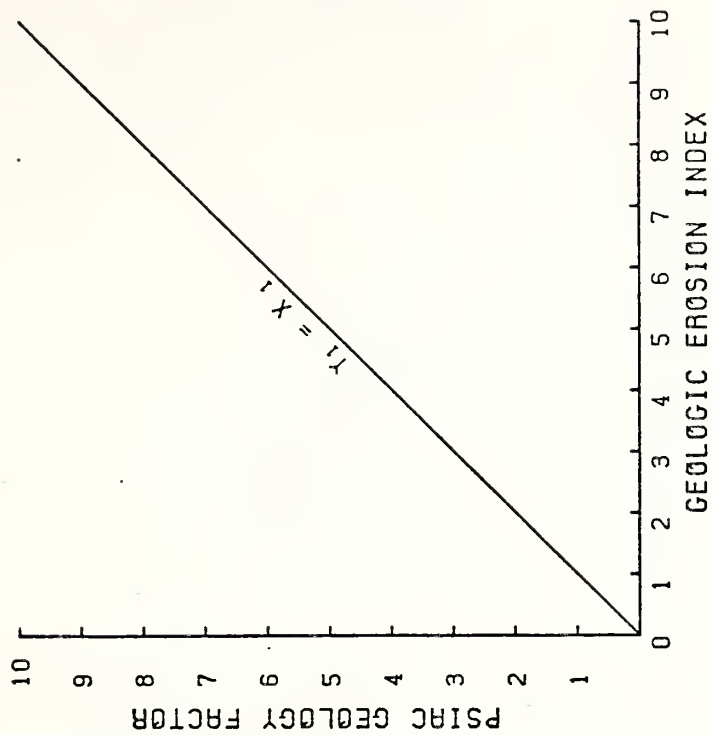


FIGURE 4.a.2.--THE RELATIONSHIP BETWEEN A GEOLOGIC EROSION INDEX AND THE PSIAC GEOLOGY FACTOR.

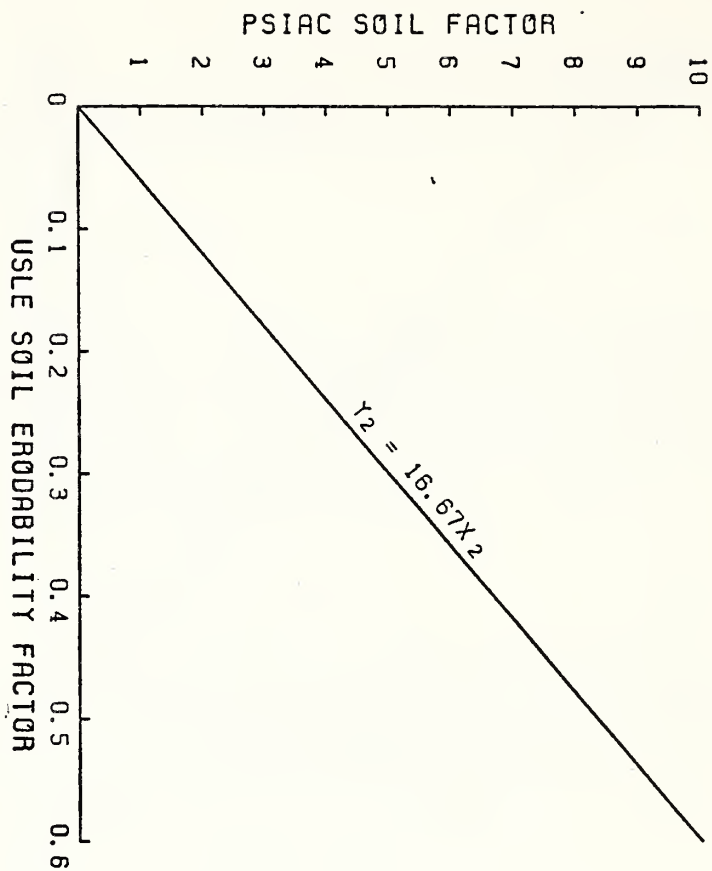


FIGURE 4.a.3.--THE RELATIONSHIP BETWEEN THE USLE SOIL ERODABILITY FACTOR AND THE PSIAC SOIL FACTOR.

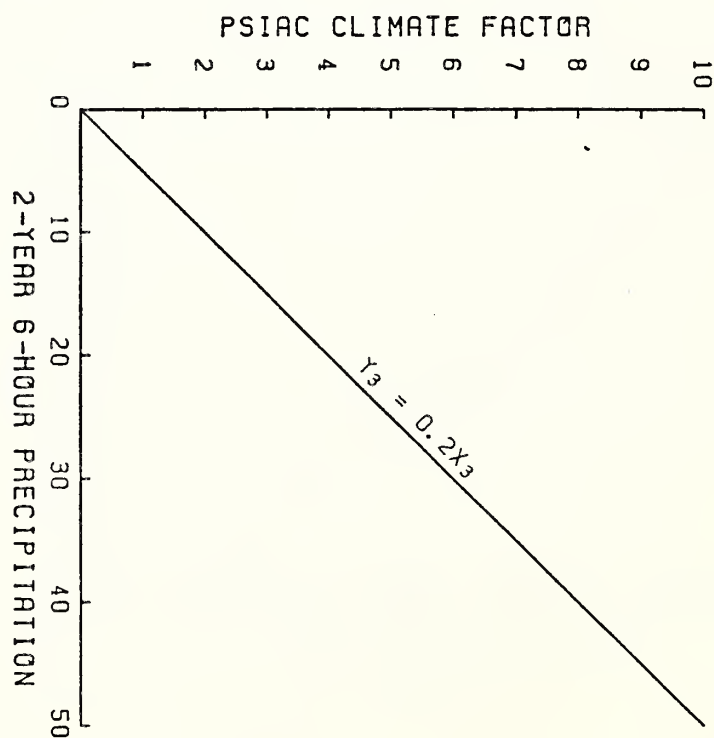


FIGURE 4.a.4.--THE RELATIONSHIP BETWEEN THE 2-YEAR 6-HOUR PRECIPITATION IN MM AND THE PSIAC CLIMATE FACTOR.

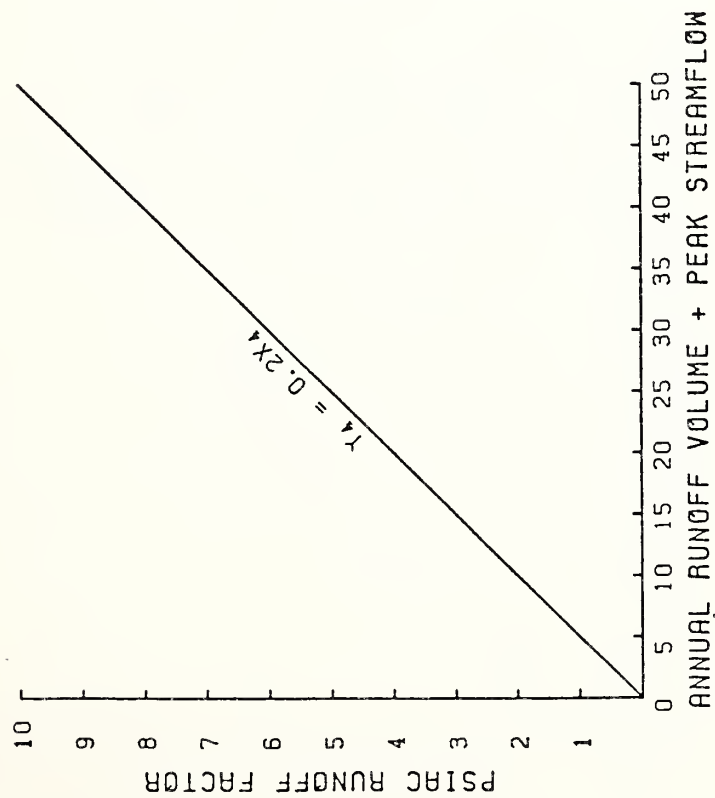


FIGURE 4.a.5.--THE RELATIONSHIP BETWEEN THE SUM OF ANNUAL RUNOFF VOLUME $(\text{mm} \times 0.05)$ AND PEAK STREAMFLOW $(\text{m}^3/\text{sec}/\text{km}^2 \times 50)$ AND THE PSIAC RUNOFF FACTOR.

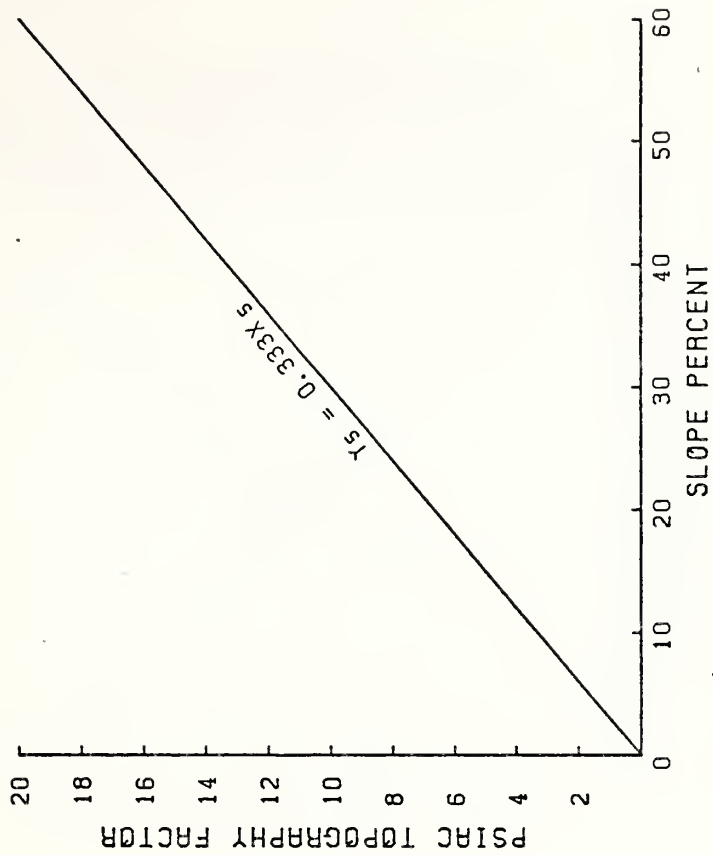


FIGURE 4.a.6.--THE RELATIONSHIP BETWEEN SLOPE PERCENT AND THE PSIAC TOPOGRAPHY FACTOR.

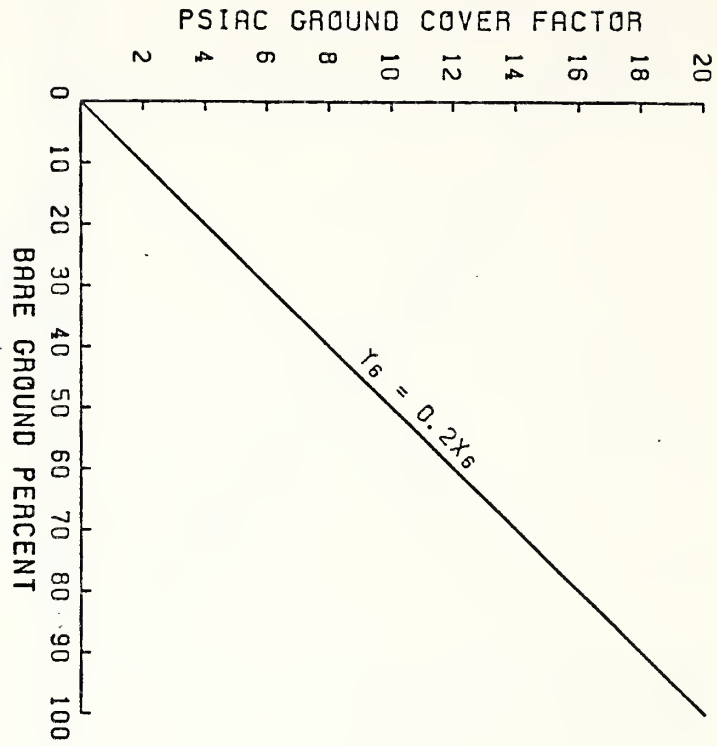


FIGURE 4.a.7.--THE RELATIONSHIP BETWEEN PERCENT BARE GROUND AND THE PSIAC GROUND COVER FACTOR.

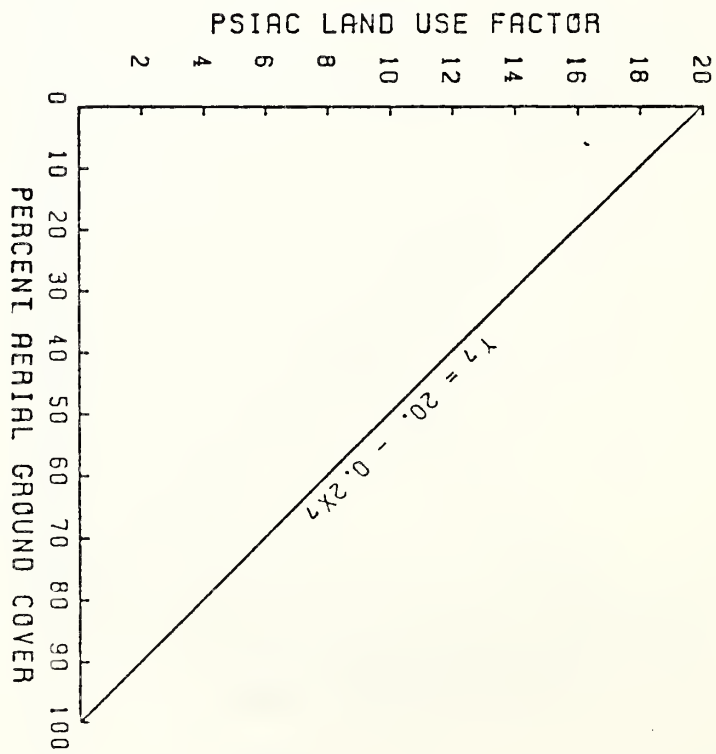


FIGURE 4.a.8.--THE RELATIONSHIP BETWEEN PERCENT AERIAL GROUND COVER AND THE PSIAC LAND USE FACTOR.

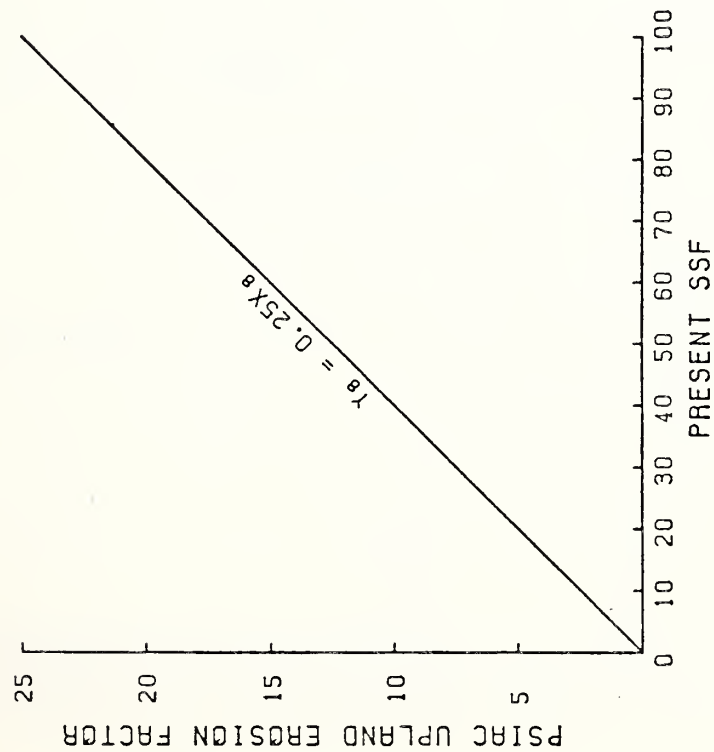


FIGURE 4.a.9.--THE RELATIONSHIP BETWEEN PRESENT SSF AND THE PSIAC UPLAND EROSION FACTOR.

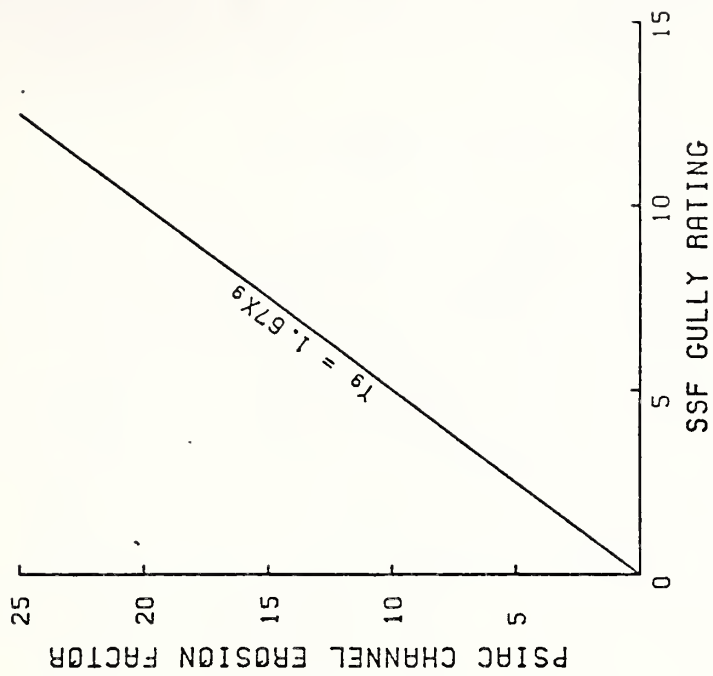


FIGURE 4.a.10.--THE RELATIONSHIP BETWEEN THE SSF GULLY RATING AND THE PSIAC CHANNEL EROSION FACTOR.

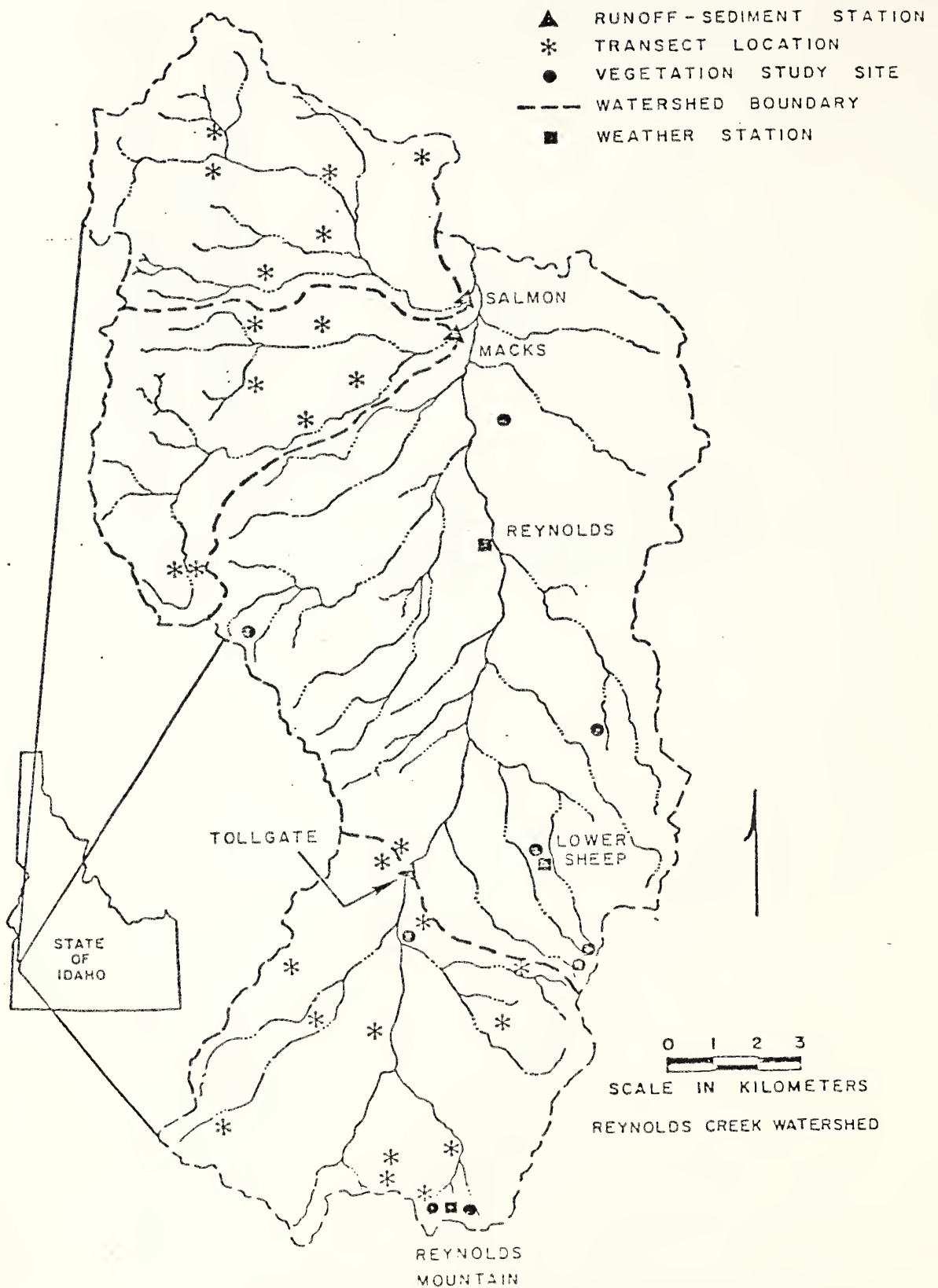


FIGURE 4.a.11.--Locations of hydrologic instrumentation, study sites, and transects, Reynolds Creek Experimental Watershed:

Watersheds were first divided into 0-10%, 11-20%, 21-30%, 31-40%, and greater than 40% slope classes. Next, each slope area was subdivided, as necessary, to delineate differences in precipitation, soils, and cover to facilitate application of the USLE and PSIAC procedure.

WATERSHED AND STUDY SITES

Sagebrush rangeland hydrologic and related research have been conducted on the Reynolds Creek Experimental Watershed in southwest Idaho since 1960 (Robins, et al., 1965). Watersheds, vegetation and grazing sites, and representative transect locations are shown in Figure 4.a.11. Watershed characteristics are listed in Table 4.a.1. Average annual precipitation, 1962 through 1978, ranged from 250 mm in the lower valley, 1190 m elevation, to 1070 mm at an elevation of 2090 m. Precipitation at the Reynolds Weather Station, 1200 m elevation, ranged from 143 mm in 1966, a drought year, to 445 mm in 1965, a wet year. Runoff ranged from zero in some years at the lowest elevations with less than 250 mm precipitation, to 885 mm in the 1965 water year at Reynolds Mountain Station, with 1676 mm precipitation. Measured sediment yields averaged from 0.02 to 1.90 t/ha/yr and were extremely variable from year to year at all stations, depending mainly on runoff conditions, Johnson and Hanson (1976) and Johnson and Smith (1978).

TABLE 4.a.1.--Watershed and vegetation study site descriptions, Reynolds Creek Experimental Watershed.

Watershed	Drainage area	Elevation range	Precipitation range	Runoff range	Measured sediment yield
	km ²	m	mm	mm	t/ha
SALMON CREEK	36.4	1120-1920	300-560	10-280	1.90
MACKS CREEK	31.8	1140-1890	300-530	10-270	1.57
REYNOLDS CREEK ABOVE TOLLCATE	54.5	1400-2230	470-1320	12-760	1.50

Study Site	Elevation	Precipitation	Grazed Bare Ground	Grazed Total Canopy	Grazed SSF
	m	mm	%	%	
FLATS	1190	250	58	41	19
NANCY	1400	350	38	34	27
WHISKEY HILL	1650	580	30	67	23
LOWER SHEEP	1650	360	25	45	24
UPPER SHEEP, S. F.	1860	500	44	42	32
UPPER SHEEP, N. F.	1860	500	16	71	8
REYNOLDS MTN., WEST	2090	1020	19	47	17
REYNOLDS MTN., EAST	2090	1020	22	80	7
NETTLETON	1500	480	32	52	17

Areas at the nine vegetation and grazing study sites were fenced to exclude cattle grazing, 1972 through 1979, and cover transects were run once or twice each year on grazed, ungrazed, and brush treatment areas, Schumaker and Hanson (1977).

RESULTS AND DISCUSSION

Soil loss predictions: The maximum, minimum, and area weighted mean USLE factor values for the Salmon Creek, Macks Creek, and Reynolds Creek above Tollgate watersheds within the Reynolds Creek Experimental Watershed are summarized in Table 4.a.2. The greatest predicted soil loss, 2.74 t/ha, Reynolds Creek above Tollgate, is accounted for by the much larger rainfall-runoff factor, R, due to higher precipitation and snowmelt runoff. However, the next highest soil loss, 2.70 t/ha, Salmon Creek, is accounted for by the large cover factor, C, due to more bare ground and less canopy cover measured on vegetative cover transects. The soil erodibility factor, K, and slope-length-steepness factor, LS, are similar on all three watersheds. The three watersheds were divided into 47 subareas to delineate major differences in slope, precipitation, soils, and cover.

TABLE 4.a.2.--Summary of USLE and PSIAC factor values for watersheds on Reynolds Creek.

FACTOR	WATERSHED								
	SALMON CREEK			MACKS CREEK			REYNOLDS TOLLGATE		
	MAX.	MIN.	MEAN ^{1/}	MAX.	MIN.	MEAN ^{1/}	MAX.	MIN.	MEAN ^{1/}
USLE:									
R	46	30	39	45	30	39	117	41	69
K	0.32	0.26	0.28	0.30	0.20	0.27	0.28	0.11	0.24
LS	15.0	1.2	5.93	12.0	1.1	5.24	15.0	1.6	5.1
C	0.04	0.01	0.022	0.02	0.01	0.013	0.028	0.01	0.014
A, t/ha	5.07	0.87	2.70	2.53	0.45	1.47	7.06	0.58	2.74
PSIAC:									
SURFACE GEOLOGY	7.0	3.0	4.18	7.0	3.0	4.83	6.0	4.0	5.2
SOILS	5.3	4.3	4.64	5.0	3.5	4.49	4.7	1.8	4.0
CLIMATE	7.8	4.8	6.37	8.0	5.0	6.93	8.1	4.8	6.6
RUNOFF	4.1	1.2	2.24	3.2	1.2	2.12	6.0	0.9	2.8
SLOPE	16.6	2.5	7.93	15.0	2.5	7.60	16.0	3.0	7.4
GROUND COVER	6.4	2.4	4.71	4.4	2.7	3.35	6.0	2.0	3.4
LAND USE	14.0	7.0	10.17	13.0	7.0	8.85	12.0	3.0	6.3
UPLAND EROSION	11.5	8.0	10.36	11.6	4.0	6.17	10.0	2.5	5.6
CHANNEL EROSION	14.0	4.0	8.92	11.0	2.0	5.39	6.0	2.0	3.5
RATING	65.9	55.0	59.5	59.6	46.3	49.2	63.8	39.4	44.8
SEDIMENT YIELD, t/ha	2.73	1.84	2.18	2.17	1.35	1.55	2.53	1.03	1.29

^{1/}Area weighted means.

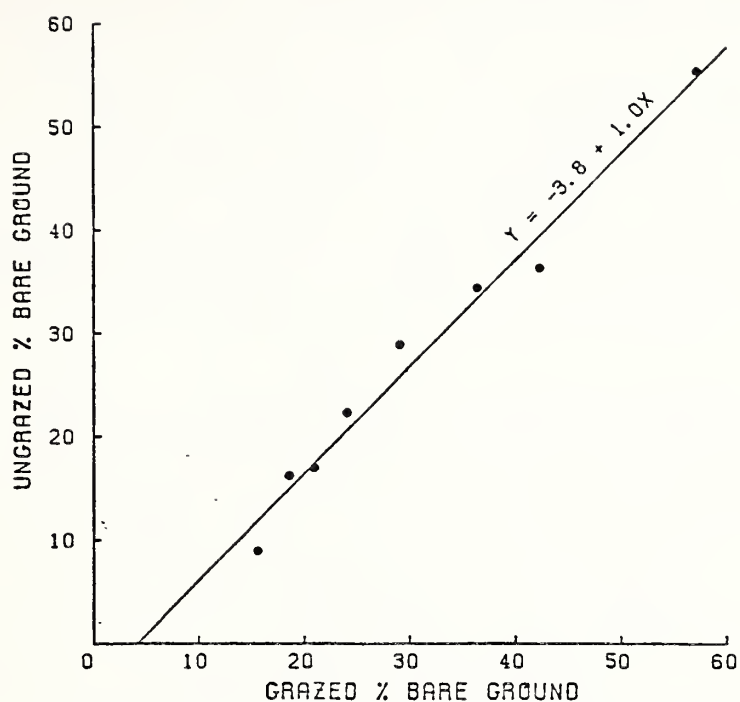


FIGURE 4.a.12.--THE RELATIONSHIP BETWEEN PERCENT BARE GROUND ON GRAZED AND UNGRAZED AREAS AT STUDY SITES.

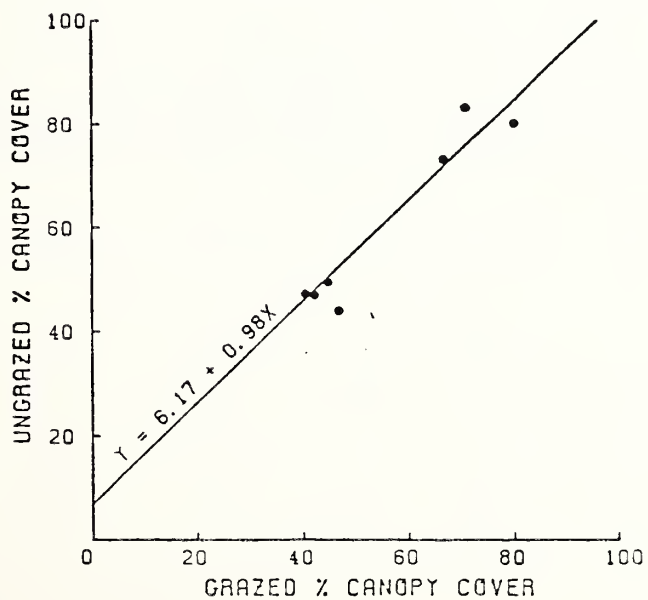


FIGURE 4.a.13.--THE RELATIONSHIP BETWEEN PERCENT CANOPY COVER ON GRAZED AND UNGRAZED AREAS AT STUDY SITES.

Sediment yield predictions and measurements: Maximum, minimum, and area-weighted mean PSIAC factor values for the three watersheds are summarized in Table 4.a.2 and show a wide range of most factors. The greatest predicted sediment yield, 2.18 t/ha, Salmon Creek, is accounted for by less ground cover, more intensive land use, and greater slope, upland erosion, and channel erosion factor values. Predicted sediment yields are within about 15 percent of measured yields, Table 4.a.1. Salmon Creek predicted yields are greater than measured yields, while Reynolds Creek, above Tollgate, predicted yields are less than measured. Considering the wide year-to-year variation in measured sediment yields and only 8 to 10 years of sediment records, the predicted yields compare favorably with measured yields.

Effects of grazing on soil loss and sediment yield: Percent bare ground, percent aerial vegetative cover, and SSF were determined on eight ungrazed and eight moderately to heavily grazed areas of the Reynolds Creek Watershed from 1972 through 1979 to evaluate the effects of grazing on USLE soil loss and PSIAC sediment yield. The relationships between grazed and ungrazed areas for bare ground, aerial vegetative cover, and SSF are shown in Figures 4.a.12, 4.a.13, and 4.a.14, respectively. The differences in computed soil loss and sediment yield were determined by changing the USLE C factor and PSIAC ground cover, land use, and upland erosion factors, as appropriate from Figures 4.a.12 through 4.a.14. Results, Table 4.a.3 show that excluding cattle grazing for 8 years reduced predicted on-site soil loss about 0.5 t/ha/yr and sediment yield about 0.2 t/ha/yr.

TABLE 4.a.3.--Comparisons of USLE soil loss and PSIAC sediment yield based on data from ungrazed and grazed watersheds.

	WATERSHED					
	SALMON CREEK		MACKS CREEK		REYNOLDS TOLLGATE	
	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed
USLE:						
C	0.013	0.022	0.010	0.013	0.011	0.014
A, t/ha	2.21	2.70	1.13	1.47	2.15	2.74
PSIAC:						
GROUND COVER	3.95	4.71	2.59	3.35	2.64	3.40
LAND USE	9.13	10.17	7.84	8.85	5.34	6.30
UPLAND EROSION	9.47	10.36	5.41	6.17	4.86	5.60
SEDIMENT YIELD, t/ha	1.97	2.18	1.36	1.55	1.17	1.29

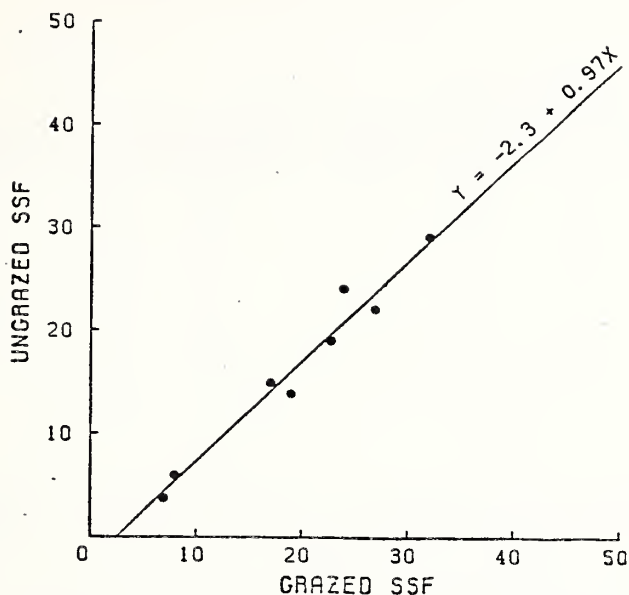


FIGURE 4.a.14.--THE RELATIONSHIP BETWEEN SSF VALUES ON GRAZED AND UNGRAZED AREAS AT STUDY SITES.

The effects of extremely heavy cattle grazing, about 90 percent forage utilization, on soil loss and sediment yield were estimated at one of the vegetation study sites, Figure 4.a.11. Average 1972 through 1978 data at the site showed 32 percent bare ground, 52 percent aerial ground cover, and an SSF of 17 on the grazed area and 17 percent bare ground, 65 percent aerial ground cover, and an SSF of 9 on the ungrazed area. The resulting estimated USLE soil loss and PSIAC sediment yield were 1.90 and 1.34 t/ha on the heavily grazed areas, and 0.75 and 1.02 t/ha on the ungrazed areas, respectively. The greater percent bare ground on the grazed area caused an extreme increase in estimated USLE soil loss, but less increase in sediment yield, showing the greater sensitivity of the USLE to on-site changes caused by grazing.

Effects of sagebrush eradication treatments: Sagebrush was cut and removed from three ungrazed sites and was sprayed with 2,4-D or 2,4-T at four ungrazed sites to improve forage production and to study vegetative cover changes, 1972-1975. Results from this study (Schumaker and Hanson, 1977) were analyzed by the USLE and PSIAC procedure to estimate the effects of the sagebrush eradication treatments on soil loss the sediment yield, Table 4.a.4. Generally, the ungrazed areas without sagebrush treatment showed less soil loss and sediment yield than areas where sagebrush was removed or killed by spraying. The greatest increase in soil loss on the Upper Sheep site, 2.4 t/ha/yr, was mainly due to the 25 percent slope and removal of a dense sagebrush cover. The USLE is more sensitive to changes in vegetative cover than the PSIAC procedure, which showed only about 0.1 t/ha/yr increase in sediment yield where sagebrush was cut and removed.

Table 4.a.4.--Estimated USLE soil loss and PSIAC sediment yield, t/ha, at sagebrush treatment sites, Reynolds Creek Experimental Watershed, 1972-75.

Treatment	Site							
	Nancy		Whiskey Hill		Upper Sheep, N.F.		Reynolds Mtn. E.	
	USLE	PSIAC	USLE	PSIAC	USLE	PSIAC	USLE	PSIAC
Ungrazed	0.56	1.37	0.71	1.14	1.06	0.90	0.86	0.82
Grazed	0.70	1.59	0.71	1.23	2.45	1.03	0.97	1.02
Sprayed	0.63	1.31	0.94	1.15	1.75	0.98	1.04	1.05
Cut	0.97	1.41	--	--	3.47	1.06	1.16	0.94

Effects of stony soils: Surface stones and rock were included as ground cover in determining the USLE cover and management factor, C, values and the PSIAC percent bare ground to compute soil loss and sediment yield in this study. However, the additional reduction in erosion due to the stony soils was evaluated as recommended by the Soil Conservation Service (1974), page 2:

"K values for soils high in coarse fragments (gravelly, chanery, shaly, slaty, cherty, cobbly, or flaggy) are reduced by one or two classes. Soils that are very gravelly, very chanery, very shaly, very slaty, very cherty, very cobbly, or very flaggy are reduced by two or three classes."

Soil erodibility, soil loss, and sediment yields for Salmon Creek, Macks Creek, and Reynolds Creek above Tollgate watersheds were adjusted for stony soils using data from a detailed soil survey, Stephenson (1977), Table 4.a.5. Results show that computed USLE soil loss was reduced 15-19 percent and computed sediment yield was reduced 1-4 percent due to the stony soils. The USLE was much more sensitive to stony soils than the PSIAC procedures.

Effects of irregular slopes on soil loss: Soil loss from a watershed slope is affected by the shape of the slope. Since use of average slope gradient would underestimate soil loss on convex slopes and overestimate soil loss on concave slopes, the procedure developed by Wischmeier and Smith (1978) was used to analyze slopes on the watershed in this study.

Watershed slope sections on maps of Salmon Creek, Macks Creek, and Reynolds Creek above Tollgate were selected, plotted, and evaluated in four segments to determine the percent increase or decrease in soil loss compared with a uniform slope shape. Results, Table 4.a.6, show that 49 slope sections were concave, 55 slope sections were convex, and 2 slope sections were uniform. Slope sections were evenly

Table 4.a.5.--Watershed comparisons of areas with stony soils and resulting decrease in soil erodibility, soil loss, and sediment yield.

	Watershed		
	Salmon Creek	Macks Creek	Reynolds Cr. at Tollgate
Area with extremely stony soil, %	8	2	1
Area with very stony soil, %	50	41	26
Area with stony soil, %	37	38	47
Area without stony soil, %	5	19	26
USLE soil erodibility, unadjusted	0.28	0.27	0.24
USLE soil erodibility, adjusted	0.22	0.23	0.20
USLE soil loss, unadjusted, t/ha	2.70	1.47	2.74
USLE soil loss, adjusted, t/ha	2.18	1.25	2.28
Reduction in soil loss by stony soil	19%	15%	17%
PSIAC sediment yield, unadjusted, t/ha	2.18	1.55	1.29
PSIAC sediment yield, adjusted, t/ha	2.09	1.45	1.25
Reduction in sediment yield by stony soil	4%	1%	3%

Table 4.a.6.--Summary of slope shape analysis, Reynolds Creek Watersheds.

	Watershed			
	Salmon Creek	Macks Creek	Reynolds Creek above Tollgate	Total all Watersheds
Number of slope sections	36	29	41	106
<u>Convex slopes:</u>				
Number of sections	15	15	25	55
Average soil loss increase, %	6.9	6.1	6.5	6.5
Range of increase, %	1-18	1-20	1-22	
<u>Concave slopes:</u>				
Number of sections	21	14	14	49
Average soil loss decrease, %	5.7	8.3	4.6	6.2
Range of decrease, %	1-12	1-18	1-11	
<u>Uniform slopes:</u>				
Number of sections	0	0	2	2

distributed on all watersheds. The average increase or decrease in soil loss was about 6 percent due to slope shape; however, about half the section showed small scale slope irregularities not accounted for in the analysis where additional deposition could occur. Overall, convex and concave slope shapes averaged quite well, but on individual small areas the slopes ranged widely from concave to convex and show that each area of interest must be evaluated separately.

SUMMARY AND CONCLUSIONS

Average yearly predicted sediment yields from three Reynolds Creek watersheds by the PSIAC procedure ranged from 1.5 to 1.9 t/ha. However, watershed subareas showed predicted yields from 1.0 to 2.7 t/ha, in response to a wide range in PSIAC factor values. By comparison, USLE predicted soil losses range from 0.45 to 5.07 t/ha. Overall, PSIAC sediment yield was about 70 percent of USLE soil loss on a watershed basis.

Moderate to heavy cattle grazing increased USLE soil loss about 0.5 t/ha/yr and PSIAC sediment yield about 0.2 t/ha/yr, based on differences in vegetative cover on grazed and ungrazed areas over 8 years. Extremely heavy cattle grazing increased USLE soil loss 1.15 t/ha/yr and PSIAC sediment yield 0.32 t/ha/yr. USLE soil loss was increased about 0.35 t/ha/yr on slopes less than 15 percent and about 2.4 t/ha/yr on a slope greater than 25 percent where sagebrush was cut and removed.

PSIAC sediment yield was only increased about 0.1 t/ha/yr where sagebrush was cut and removed. Sagebrush eradication by spraying had less effect on soil loss and sediment yield than moderate-to-heavy grazing.

The stony soils on the study watersheds caused an estimated 15-19 percent reduction in soil loss and 1-4 percent reduction in sediment yield. This effect can be especially important on areas with extensive coarse surface rock. Also, watershed slopes showed a wide range in shape from concave to convex, with about 6 percent average increase or decrease in estimated soil loss with each condition. Small slope irregularities, not accounted for in the slope shape analysis, are probably very effective in further reducing soil loss from about half the slopes studied. Obviously, these slope shapes and stony soils must be carefully analyzed in estimating soil loss and sediment yield from individual areas.

The USLE slope-steepness factor, as presently used, has been questioned by Jurinak, et al., (1977), based on the analysis of Horton (1945); therefore, additional research is needed in applying the equation on slopes steeper than 40 percent. Also, rangeland soils and vegetation have not been adequately evaluated by USLE rainulator studies.

The USLE and PSIAC sediment yield prediction procedure developed in this study need wider application and verification; however, results in this study are in acceptable agreement with measured watershed sediment

yields and provide a method for comparing and predicting effects of site conditions and management changes. Measured and predicted sediment yields in this study with runoff exceeding 51 mm, were only about 1/4 to 1/3 of yields predicted by equation [6] of Dendy and Bolton (1976) for the United States. Obviously, rangeland sediment yields cannot be accurately predicted from such a nationwide analysis.

Sediment sampling at four Reynolds Creek sites

(Reynolds Creek Experimental Watershed station locations are shown in the Introduction, Figure 1.)

MICROWATERSHEDS

Too few samples were obtained during the winter runoff events for a meaningful analysis and no severe summer storms occurred.

SOURCE WATERSHED

Reynolds Mountain East: Total sediment yield from this 100-acre watershed in 1979 was 9.2 tons, 70 percent of the 11-year mean, 13.2 tons, Table 4.a.7. The maximum suspended sediment concentration was about 300 mg/l.

TRIBUTARY WATERSHED

Macks Creek: Suspended sediment yield from this 7846-acre watershed was 1634 tons in 1979, about 68 percent of the 12-year mean, Table 4.a.7. About 50 percent of the yearly sediment yield was on January 11, 1979, with the peak streamflow from rain and snow-melt on frozen soil. The maximum suspended sediment concentration was 5000 mg/l.

MAIN STEM WATERSHEDS

Reynolds Creek at Outlet: Suspended sediment yield from the 57,754-acre watershed was 11,674 tons in 1979, 84 percent of the 13-year mean, Table 4.a.7. Nearly 50 percent of the yearly sediment yield was during the January 11, 1979 storm. The maximum suspended sediment concentration was 6980 mg/l.

Reynolds Creek at Tollgate: Total sediment yield from this 13,453-acre watershed was 1808 tons, 33 percent of the 13-year mean, Table 4.a.7. About 16 percent of the yearly sediment yield was on March 6, 1979, when the maximum yearly suspended sediment concentration was 6840 mg/l. Bedload was about 8 percent of total sediment yield.

TABLE 4.a.7.--Sediment yield in tons at Reynolds Creek Watershed Stations.

Year	Reynolds Mountain East	Macks ^{1/} Creek	Reynolds Creek at Tollgate	Reynolds ^{1/} Creek at Outlet
1967	---	---	11275	13503
1968	5.5	393	1965	4334
1969	17.0	6332	12994	39336
1970	31.1	3585	7242	15369
1971	18.1	5833	9771	28641
1972	18.3	5414	8838	37396
1973	9.4	1147	1203	2415
1974	10.3	1214	2774	5762
1975	14.2	1949	7867	9860
1976	12.4	646	2546	1430
1977	1.0	7	51	3257
1978	12.1	554	2797	8256
1979	9.2	1634	1808	11674
MEAN	13.2	2392	5472	13941

^{1/} Suspended sediment only.

References: Section 4.a.

- Clawson, M., and B. Held. 1957. The federal lands. The John Hopkins Press, Baltimore, Maryland.
- Dendy, F. E., and G. C. Bolton. 1976. Sediment yield-runoff drainage area relationships in the United States. Journal of Soil and Water Conservation 31(6): 264-266.
- Horton, R. E. 1945. Erosional development of streams and their drainage basins, hydrophysical approach to quantitative morphology. Geological Society of America, Bulletin 56: 275-370.
- Johnson, C. W., and C. L. Hanson. 1976. Sediment sources and yields from sagebrush rangeland watersheds. p 1-70 to 1-80. In Proceedings of the Third Inter-Agency Sedimentation Conference, Denver, Colorado.
- Johnson, C. W., and J. P. Smith. 1978. Sediment characteristics and transport from northwest rangeland watersheds. Transactions of the American Society of Agricultural Engineers 21(6): 1157-1163, 1168.
- Jurinak, J. J., W. J. Grenney, G. L. Wooldridge, J. P. Riley, and R. J. Waganet. 1977. A model of environmental transport of heavy metals originating from stock derived particulate emissions in semi-arid regions. Report prepared for Southern California Edison Company, Utah State University, Logan, Utah. 143 pp.
- Leifeste, B. 1978. Unpublished paper, "Pacific Southwest Inter-Agency Committee (PSIAC) methodology for estimating sediment yield on semi-arid watersheds and relationships to Bureau inventory base," presented at Nevada-Utah Watershed Workshop, 1978.
- McCool, D. K., R. I. Papendick, and F. L. Brooks. 1976. The Universal Soil Loss Equation as adapted to the Pacific Northwest. p 2-135 to 2-147. In proceedings of the Third Inter-Agency Sedimentation Conference, Denver, Colorado.
- McIntyre, D. H. 1972. Cenozoic geology of the Reynolds Creek Experimental Watershed, Owyhee County, Idaho. Idaho Bureau of Mines and Geology, Pamphlet 151. University of Idaho, Moscow, Idaho.
- Pacific Southwest Inter-Agency Committee. 1968. Report on factors affecting sediment yields in the Pacific Southwest area. Water Management Subcommittee, Sedimentation Task Force. 10 pp.
- Richerson, P., and R. Johnston. 1975. Environmental values and water quality planning. Journal of the Hydraulics Division, American Society of Civil Engineers. 101(HY2): 259-276.

Robins, J. S., L. L. Kelly, and W. R. Hamon. 1965. Reynolds Creek in southwest Idaho: An outdoor hydrologic laboratory. Water Resources Research 1(3):407-413.

Schumaker, G. A., and C. L. Hanson. 1977. Herbage response after mechanical and herbicide treatment of big sagebrush in southwest Idaho. USDA, Western Region ARS W-46, 15 pp.

Soil Conservation Service. 1974. Soil erodibility and soil loss tolerance factors for Idaho soils. USDA, 27 pp.

Shown, L. M. 1970. Evaluation of a method for estimating sediment yield. USDI, USGS Prof. Paper 700-B, p. B 245-B 249.

Stephenson, G. R. 1977. Soil geology vegetation inventories, Reynolds Creek Experimental Watershed, Idaho. University of Idaho, Agricultural Experiment Station, Miscellaneous Series No. 42, 66 pp.

Wischmeier, W. H., and D. D. Smith. 1978. Predicting rainfall erosion losses--a guide to conservation planning. USDA, Agricultural Handbook No. 537, 58 pp.

Wischmeier, W. H. 1975. Estimating the soil loss equations' cover and management factor for undisturbed areas, p. 118-124. In Proceedings of the Sediment Yield Workshop, USDA, ARS-S-40, Oxford, Mississippi.

b. Boise Front

Sediment Sampling at Three Boise Front Sites

(Boise Front runoff and sediment sampling station locations are shown in the Introduction, Figure 2.)

Upper Maynard Gulch: Suspended sediment yield from this 725-acre watershed was 12.2 tons in 1979, Table 4.b.1. The maximum suspended sediment concentration was about 1500 mg/l during peak runoff events. Over half the yearly sediment yield occurred on January 11 and February 13 from rain, snowmelt, and frozen soil events.

Lower Maynard Gulch: Suspended sediment yield from this 1369-acre watershed, which includes Upper Maynard Gulch, was 81.2 tons, Table 4.b.1. The maximum suspended sediment concentration was about 3500 mg/l on February 9, 1979. About 40 percent of the yearly sediment yield occurred on January 11, with peak streamflow. Additional, but unmeasured, bedload sediment was evident in weir pond deposition.

Highland Creek: Total sediment yield from this 988-acre watershed was 44.5 tons in 1979, Table 4.b.1. The maximum suspended sediment concentration was about 3000 mg/l on January 11, 1979. Bedload was about 36 percent of total yearly sediment yield.

Table 4.b.1.--Sediment yield from Boise Front Watersheds, 1979 Water Year.

Month	Watershed		
	Upper Maynard Gulch	Lower ^{1/} Maynard Gulch	Highland Creek
	-----tons-----		
October	0.01	0.02	0.11
November	0.07	0.05	0.34
December	0.12	0.27	0.46
January	3.16	33.66	5.83
February	4.50	38.71	7.29
March	3.09	5.81	26.41
April	0.77	1.45	2.44
May	0.41	1.26	1.23
June	0.02	0.01	0.10
July	0	0	0.01
August	0.01	0	0.11
September	0.01	0	0.14
YEAR TOTAL	12.17	81.24	44.47

^{1/} Drainage area includes Upper Maynard Gulch

5. WATER QUALITY

Personnel Involved

G. R. Stephenson,
Geologist

Responsible for coordinating activities with cooperators. Design collection network and responsible for project completion.

J. F. Zuzel,
Hydrologist
(Transferred 9-8-79)

Responsible for statistical analyses of data, water quality modeling, and shares the responsibility for aquatic sampling.

J. H. Harris,
Scientific Aid
(U. of Idaho Cooperator)

Responsible for collection of water samples and laboratory analyses.

S. C. Kroeger,
Research Technician
(U. of Idaho Cooperator)

Assists in collection of field data.

R. L. O'Brien,
Hydrologic Aid

Assists in laboratory analyses.

a. Reynolds Creek

(Reynolds Creek Experimental Watershed locations are shown in Introduction, Figure 1.)

WATER QUALITY MODEL CALIBRATION

The annual work plan for FY 1979 calls for completion of the calibration of a water quality model for the main channel of Reynolds Creek. The principle outputs of the model being tested are water temperature, dissolved oxygen content, and BOD. Total biomass and other parameters could also be incorporated. A full explanation of the model parameters and application is given in the 1978 Annual Report - Interim Report No. 9. Calibration and verification results follow.

Due to an error discovered in the BOD data reported in Interim Report No. 9, it was necessary to recalibrate the model. The calibration procedure used was the same as reported in last year's report, using the same data set and the correct BOD values. The results of this second calibration are listed in Table 5.a.1. Good agreement between the simulated and observed variables was again obtained.

Table 5.a.1.--Results of model calibration for water temperature, dissolved oxygen, and BOD.

Station	Temperature		Dissolved Oxygen		BOD		20 K _d	20 K ₂
	OBS.	SIM.	OBS.	SIM.	OBS.	SIM.		
135008	59.0	--	7.5	--	0.5	--	--	--
116083	64.4	64.4	7.3	7.2	0.0	0.5	0.40	1.80
106018	77.9	77.9	6.0	6.1	0.3	0.3	0.40	0.15

It was again necessary to reduce the net shortwave radiation calculated from solar altitude and percent cloud cover due to the shading of the water surface. This appears to be a serious shortcoming of the model, but could be overcome by including a shading factor in the model. This would require some estimate of the canopy density over the stream, in addition to developing a relationship between canopy density and reduction in calculated net shortwave radiation.

MODEL VERIFICATION

The model was verified by comparing simulated results with an observed data set collected on July 12, 1979 at Reynolds Creek. Travel time of the water was measured by using a float. Air temperature, water temperature,

dissolved oxygen, BOD, percent cloud cover, stream width and depth, and wind speed were measured or estimated at each station. Net shortwave radiation was calculated from percent cloud cover and solar altitude and was then subjectively reduced, using canopy cover as the reduction criterion. Other model inputs were estimated using the procedures outlined in last year's report. The reoxygenation and deoxygenation coefficients (K_2^{20} and K_d^{20}) were maintained at the calibration values shown in Table 5.a.1. The results of the verification are shown in Table 5.a.2. Results of the model are highly satisfactory, since the model was able to simulate all variables rather closely.

Table 5.a.2.--Results of model verification for water temperature, dissolved oxygen, and BOD.

REACH	TIME	Water Temperature		Dissolved Oxygen		BOD	
		OBS.	SIM.	OBS.	SIM.	OBS.	SIM.
Start	0650	51.0	--	8.0	--	1.1	--
2	0723	51.0	51.1	7.5	8.3	1.1	1.1
3	0810	52.0	51.9	7.5	8.5	0.6	0.9
4	1130	69.0	68.9	7.0	6.5	0.9	0.8
5	1510	65.0	65.1	7.0	6.9	0.8	0.7

MODEL APPLICATION

The model, in its present form, can be used to simulate water temperature, dissolved oxygen, and BOD, given a minimum amount of input data. It could also be used as a management tool. For example, a simulation of Reynolds Creek was run for July 7 and 8, 1975, using the established calibration parameters. Figure 5.a.1 shows the results of this simulation. The solid line represents dissolved oxygen concentration as calculated by the model, with prevailing stream conditions. The dashed line represents dissolved oxygen concentration given a point source of 8 mg/l at the second station. The BOD curves are also shown for both conditions. It appears, from the results shown in Figure 5.a.1, that the model has the capability to assess the downstream results of a high BOD outfall, such as that which might be associated with a high concentration of cattle near the stream.

CONCLUSIONS

1. The water quality model can produce acceptable simulations of water temperature, dissolved oxygen, and BOD on rangeland streams, given a minimum of input data.
2. The model can be used to predict the downstream effects of high oxygen demand outfalls.
3. Some system to incorporate the amount of shading by vegetation and steep canyon walls should be developed and incorporated in the model.
4. Since the model is of simple structure and consists of linked sub-routines, it is possible to add other water quality variables with little effort or additional complexity.
5. Run times and computer core storage required are relatively low.
6. All model outputs are extremely sensitive to net shortwave radiation input.

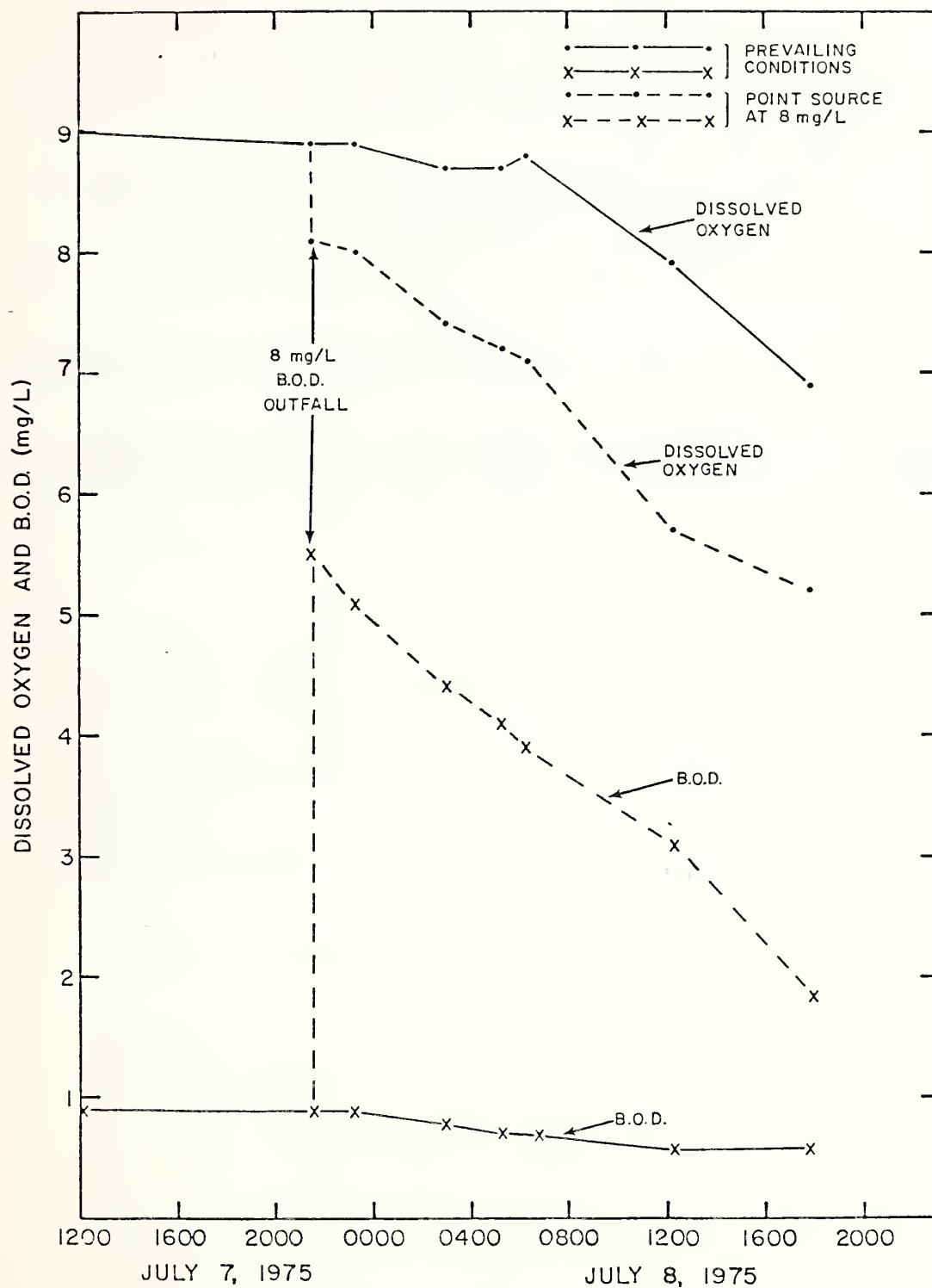


Figure 5.a.1.--Model application with prevailing conditions and with example of elevated BOD outfall for reach 2, Reynolds Creek.

WATER QUALITY REPORT

As part of the work plan for fiscal year 1979, a summary of the water quality study for the Reynolds Creek Watershed, conducted from September 1972 to October 1978, is being prepared. The major objectives of this study covered in the report are to:

1. Determine source of nonpoint pollution on rangeland streams under different levels of grazing management.
2. Determine the cause of annual, seasonal, and daily variations within nonpoint source indicators.
3. Develop and verify improved grazing management practices for reducing nonpoint source pollution in rangeland streams.

The report will appear as a Western Region Publication, USDA-SEA-AR, from the Northwest Research Center, Boise, Idaho. Plans are to have it available by June 1, 1980.

b. Boise Front

(Map of Boise Front with location of water quality sampling sites is found on Figure 2, in the Introduction section.)

BASELINE WATER QUALITY INFORMATION

Water quality baseline information continues to be developed from samples collected at four sampling sites on the Boise Front rest-rotation grazing system. The four sites are located immediately upstream from weirs, which record runoff continuously. The sampling sites are located such that the data will reflect the various land-use practices.

Results of analyses of the various water quality parameters are given on Table 5.b.1. Total number of samples varies because of intermittent flow at several locations.

Comparing the results of the 1979 data with those reported in 1978, Table 5.b.1, differences are very slight. The major differences between sites from the previous year occur because of the rotation in grazing. The fields grazed in 1978 differ from those grazed in 1979. More detailed discussion follows.

BACTERIAL INDICATORS FROM STREAMS IN THE REST-ROTATION SYSTEM

A detailed review of the rest-rotation system on the Boise Front is given in Section 2, page 47. Briefly, the fall 1978 sheep drive passed through the system from October 26 through December 1, using pastures H3, L3, L2, and L1, respectively. In 1979, the spring sheep drive was May 14 to June 2, through pastures H1, L1, L2, H2, and H3, respectively. The approximate course of the sheep drive is given on Figure 5.b.1. Cattle were grazed in pasture L3 from April 19 through June 12, and pasture H3 from June 13 through October 1. The remaining fields were rested from cattle grazing during this season. (See Figure 5.b.1.)

The effect these grazing practices have on the fecal coliform bacteria concentrations is evident by the graphs on Figure 5.b.2.

At the Lower Maynard site, in L2, fecal coliform concentrations increased in mid-May as the spring sheep drive passed through. The concentrations remained high until mid-June when the stream went dry. Elevated concentrations in February are the result of deer browsing in the area. The Camp Creek site, located in L3, shows the effect of cattle in the area by mid-April. The fecal coliform concentrations increase abruptly and remain high until the stream dried up by late May. The Upper Maynard site, which measures streamflow from H2, shows the effect of sheep passing through in late May - early June as they moved out of L2. No cattle grazing occurred in this pasture this grazing season. Large concentrations of deer were

TABLE 5.b.1.--Water quality characteristics, Reynolds Creek Watershed sampling sites, 1978-79.

Parameters	Units	No. of Samples (1979)	Maximum		Minimum		Average	
			1978	1979	1978	1979	1978	1979
Lower Maynard								
pH	units	17	8.30	8.35	7.5	6.67	7.86	7.73
Conductivity	µmhos	17	190.00	190.00	62.00	60.00	124.64	116.47
Dissolved solids	mg/l	17	131.10	149.97	42.78	54.23	86.00	114.05
Calcium	mg/l	7	--	19.34	--	10.52	--	14.52
Magnesium	mg/l	8	--	2.95	--	2.00	--	2.35
Sodium	mg/l	8	--	15.49	--	3.00	--	7.90
Phosphorous	mg/l	1	--	0.03	--	0.03	--	0.03
Nitrate	mg/l	1	--	0.03	--	0.03	--	0.03
SiO ₂	mg/l	3	--	36.00	--	21.50	--	32.78
Sodium adsorption ratio	ratio	7	--	0.92	--	0.18	--	0.56
Suspended solids	mg/l	18	41.20	167.60	2.00	3.00	12.49	21.28
Total coliform	cts/100 ml	21	2000.00	980.00	0.00	0.00	298.19	234.00
Fecal coliform	cts/100 ml	21	1720.00	675.00	0.00	0.00	225.56	81.52
Fecal strep	cts/100 ml	21	305.00	3320.00	8.00	0.00	101.50	431.81
COD	mg/l	8	15.60	6.14	6.30	0.00	8.06	2.89
BOD	mg/l	10	2.00	3.40	0.00	0.00	1.32	1.05
DO	mg/l	17	10.50	10.00	7.00	5.50	8.75	8.35
Camp Creek								
pH	units	4	8.50	8.20	7.40	6.92	7.94	7.68
Conductivity	µmhos	3	190.00	105.00	90.00	100.00	130.78	101.67
Dissolved solids	mg/l	3	131.10	115.92	62.10	99.36	90.24	107.02
Calcium	mg/l	1	--	11.23	--	11.23	--	11.23
Magnesium	mg/l	1	--	2.64	--	2.64	--	2.64
Sodium	mg/l	1	--	9.76	--	9.76	--	9.76
Phosphorous	mg/l	1	--	0.03	--	0.03	--	0.03
Nitrate	mg/l	1	--	0.03	--	0.03	--	0.03
SiO ₂	mg/l	1	--	32.00	--	32.00	--	32.00
Sodium adsorption ratio	ratio	1	--	0.68	--	0.68	--	0.68
Suspended solids	mg/l	3	--	19.00	--	3.00	--	11.50
Total coliform	cts/100 ml	16	472.00	775.00	0.00	12.00	165.57	139.67
Fecal coliform	cts/100 ml	16	280.00	528.00	0.00	0.00	38.57	110.33
Fecal strep	cts/100 ml	16	345.00	550.00	4.00	4.00	80.21	124.33
COD	mg/l	--	9.20	--	3.70	--	6.88	--
BOD	mg/l	--	--	--	--	--	--	--
DO	mg/l	3	10.50	10.00	7.50	9.50	8.81	9.67
Upper Maynard								
pH	units	19	8.30	8.20	7.30	6.53	7.77	7.70
Conductivity	µmhos	18	230.00	200.00	49.00	60.00	123.08	110.28
Dissolved solids	mg/l	18	158.70	158.63	33.81	66.65	84.93	110.77
Calcium	mg/l	6	23.45	18.61	18.24	9.10	20.84	12.57
Magnesium	mg/l	7	3.40	2.87	2.92	1.65	3.16	1.92
Sodium	mg/l	7	12.18	8.00	10.58	2.90	11.39	5.65
Phosphorous	mg/l	2	0.05	0.03	0.02	0.03	0.04	0.02
Nitrate	mg/l	2	0.06	0.02	0.04	0.02	0.05	0.02
SiO ₂	mg/l	2	36.10	39.55	26.06	20.00	31.08	29.78
Sodium adsorption ratio	ratio	6	0.62	0.59	0.61	0.17	0.62	0.44
Suspended solids	mg/l	19	30.40	23.50	0.00	2.00	7.76	7.63
Total coliform	cts/100 ml	23	1580.00	2300.00	40.00	0.00	433.88	382.13
Fecal coliform	cts/100 ml	23	780.00	1322.00	0.00	0.00	217.35	230.13
Fecal strep	cts/100 ml	23	2005.00	3220.00	10.00	13.00	319.00	368.52
COD	mg/l	10	9.90	13.10	5.10	0.00	7.28	4.80
BCD	mg/l	11	2.50	2.50	0.50	0.00	1.50	0.55
DO	mg/l	19	11.00	10.00	8.00	7.00	8.94	8.24
Highland Valley								
pH	units	29	8.40	8.10	7.41	6.50	7.77	7.52
Conductivity	µmhos	29	173.00	225.00	70.00	70.00	116.36	126.03
Dissolved solids	mg/l	29	119.37	192.51	48.30	82.11	80.29	119.38
Calcium	mg/l	13	17.43	22.37	16.63	10.79	17.03	17.43
Magnesium	mg/l	14	4.50	3.15	4.50	2.30	4.50	2.83
Sodium	mg/l	14	9.89	14.28	9.43	2.80	9.66	9.52
Phosphorous	mg/l	2	0.27	0.16	0.23	0.05	0.25	0.10
Nitrate	mg/l	1	2.00	0.24	0.62	0.24	1.31	0.24
SiO ₂	mg/l	3	37.80	42.21	27.27	26.50	32.54	34.61
Sodium adsorption ratio	ratio	13	0.56	0.76	0.52	0.19	0.54	0.53
Suspended solids	mg/l	23	132.40	210.70	2.00	2.00	52.68	23.76
Total coliform	cts/100 ml	33	3770.00	31000.00	0.00	0.00	648.06	3646.75
Fecal coliform	cts/100 ml	33	2020.00	23200.00	0.00	0.00	193.10	1295.06
Fecal strep	cts/100 ml	32	4960.00	99000.00	8.00	0.00	811.21	5655.69
COD	mg/l	10	29.40	39.57	7.80	2.00	15.51	9.61
BOD	mg/l	18	3.00	6.40	1.00	0.00	1.94	1.65
DO	mg/l	29	10.50	9.50	7.50	6.00	8.76	7.76

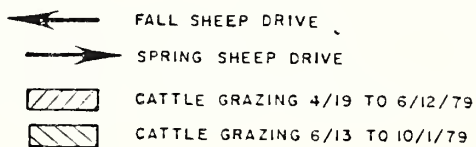
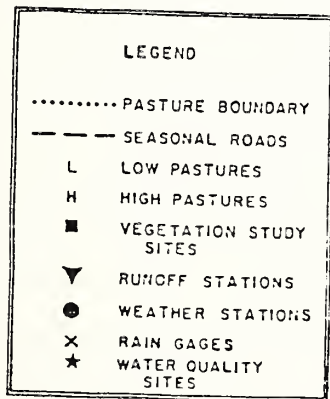
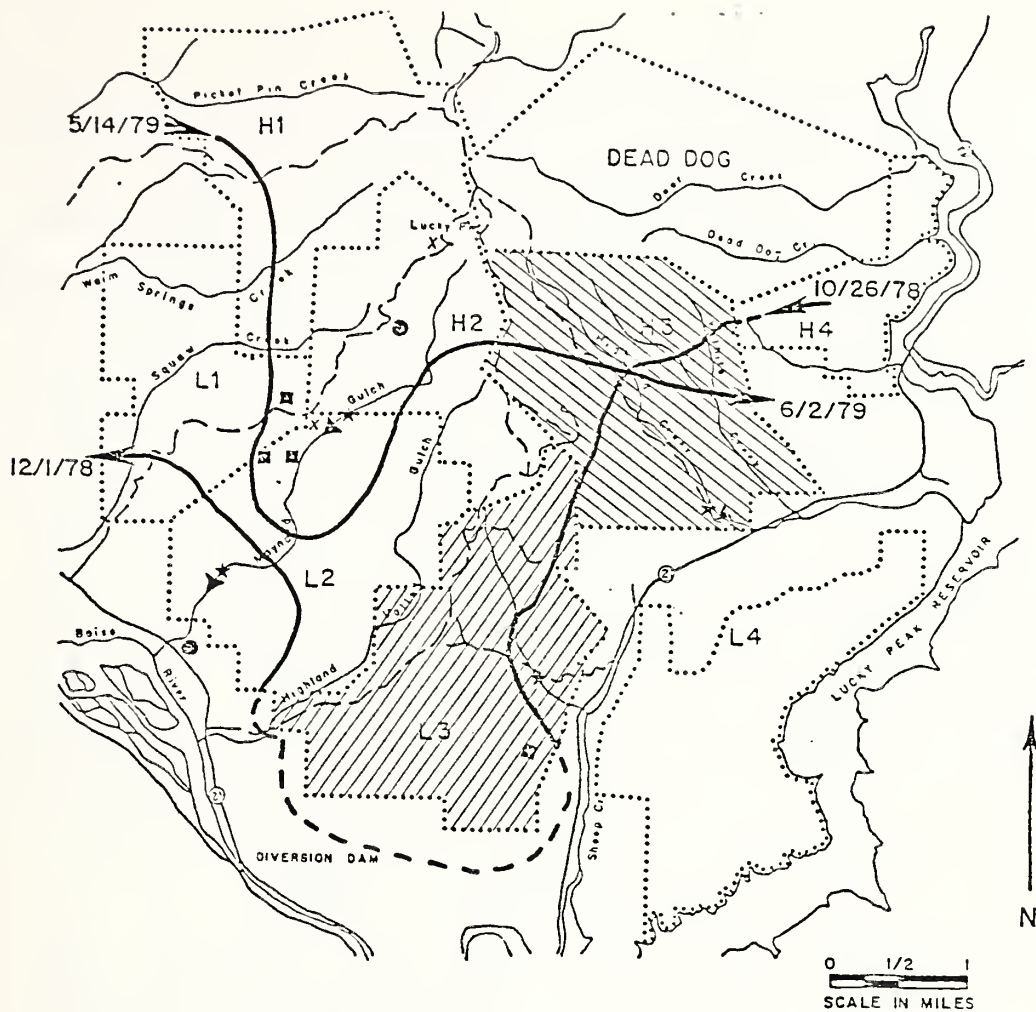


Figure 5.b.1.--Boise Front Watersheds indicating approximate course of spring and fall sheep drives and allotments grazed by cattle.

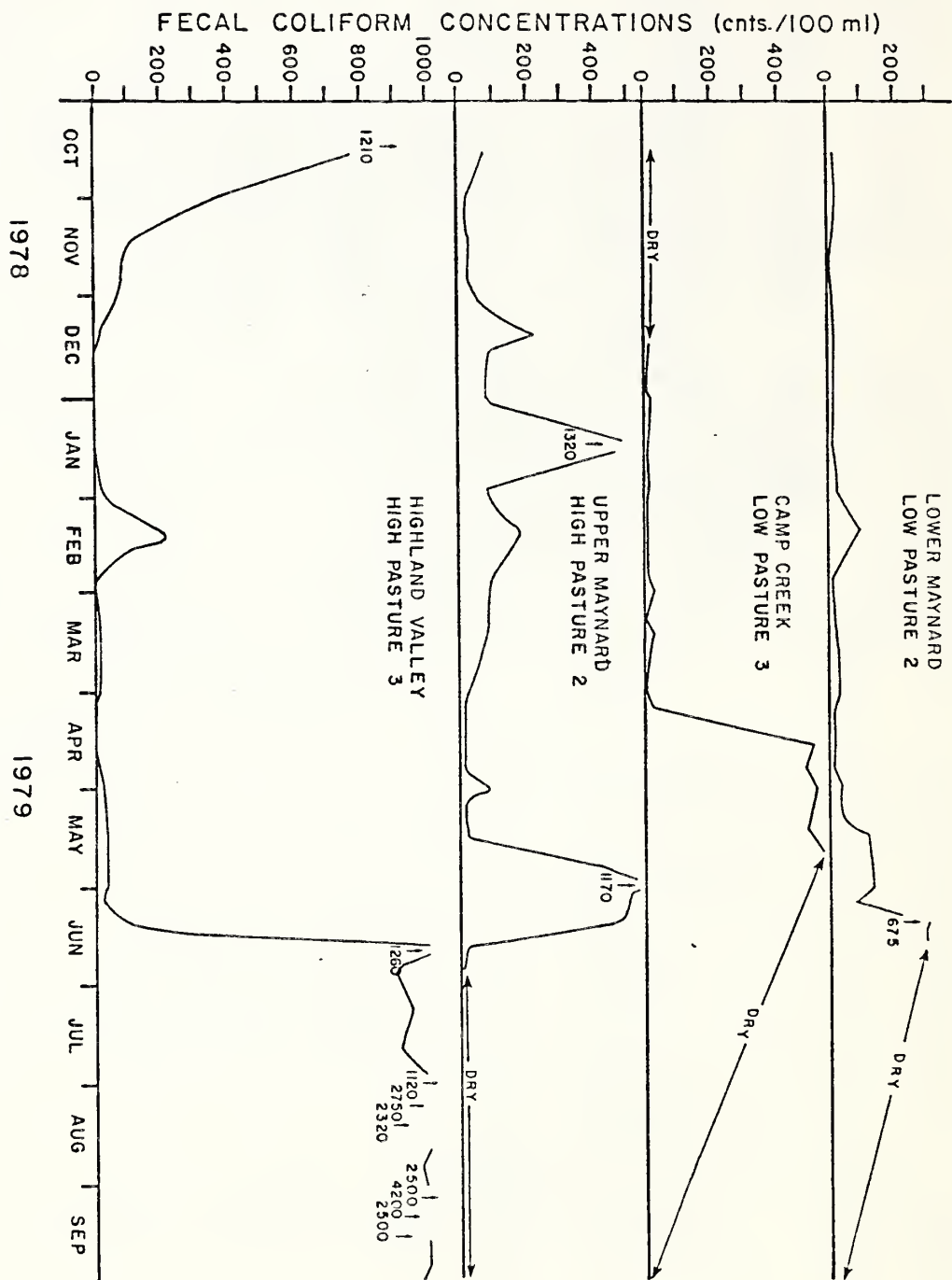


Figure 5.b.2.--Fecal coliform concentrations. Boise Front sampling sites.

observed during the winter months above the sampling site. Their presence is probably the cause of the high fecal coliform concentrations from December to March. The deer herd concentrated above this site longer than usual, resulting in fecal coliform concentrations higher than any previously recorded in relation to deer.

The Highland Valley site, located in H3, shows high fecal coliform concentrations in October, which is the result of the band of sheep located there at the time. The sheep moved out in late October, resulting in lower fecal coliform concentrations. Cattle were moved out of L3 into H3 by mid-June. Very high fecal coliform concentrations were recorded at the Highland Valley site through the remainder of the grazing season. The cattle were not moved out until October 1. Deer were present above the site throughout most of the winter, especially evident in late January and February.

The different grazing practices of deer, cattle, and sheep each have a significant effect on the fecal coliform concentrations of the streams. One can see in this study the relative effects of each, because there is very little overlap in the presence of the different animals in any one pasture. The cattle, of course, reflect the highest indicator concentration and the deer generally the least. The numbers and distribution of each group vary, causing random concentrations.

ATYPICAL E. coli IN RANGELAND STREAMS

In the examination of rangeland stream waters for fecal coliform indicators, pale yellow colonies were found to appear regularly on M-FC medium plates. The standard fecal coliform colony is typically pale to dark blue. In the past, only the blue colonies have been counted as fecal coliforms, as recommended by Standard Methods, the procedure used by most health and water quality labs. The yellow colonies were found to comprise as much as 70 percent of the total colonies on some M-FC plates. In all samples plated more than 80 percent of the yellow colonies identify as E. coli by the API20E system and serotyping. The atypical yellow E. coli colonies continue to be yellow on M-FC after growth in a nonselective medium. However, 50 percent of the atypical E. coli are ONPG-positive, and 20 percent are EC positive (44.5° C).

Failure to recognize these atypical yellow colonies as E. coli in water quality analysis could lead to significant errors in the estimation of the quality of rangeland streams.

BOTTOM SEDIMENT AS A SOURCE OF E. coli IN RANGELAND STREAMS

As a part of the objective to identify nonpoint pollution sources on rangeland streams, stream bottom sediments have been identified as a substantial source of E. coli (Stephenson and Rychert, 1979). Results

from samples taken from six separate rangeland streams have shown that E. coli concentrations of bottom sediments were as much as 760 times greater than that of the overlying water.

The results of this work suggest that microbiological analysis of sediments should be a part of rangeland stream water quality evaluations. Since sediment may be a significant source of fecal micro-organisms, even in the absence of grazing or during the post-grazing period, even minor disturbances of the organic bottom mass at the stream sediment interface can cause resuspension of the E. coli or other indicators, causing increased pollution of the overlying water body.

The manuscript reporting on this work is presently in review status.

6. RAINFALL SIMULATION STUDIES

Personnel Involved

C. W. Johnson,
Research Hydraulic Engineer

Coordinates investigations with other agencies, designs simulator plot network, and schedules field activities.

D. L. Brakensiek,
Research Hydraulic Engineer

Designs simulator studies related to infiltration.

C. L. Hanson,
Agricultural Engineer

Plans data collection and analysis related to vegetation and soil water measurements.

Background: Opportunities and needs for rainfall simulation studies on grazed and ungrazed sites of the Reynolds Creek Experimental Watershed have been recognized for several years. These needs were further emphasized at a Rainfall Simulator Workshop^{1/} and work planning sessions between the BLM and SEA-AR. However, at the close of 1979 a rainfall simulator is not yet available for use on the area. Therefore, a specific design and scheduling are not presently possible for reporting.

Support equipment and personnel: A 1200-gallon tank truck, tank trailers, pumps, and other equipment are available at Reynolds Creek. Also, a Research Hydrologist is joining the staff at the Northwest Hydrology Research Center about February 1980. In addition, other technical personnel are available to assist in simulator operation and data analysis.

Potential sites: Nine grazed and ungrazed sites, where data on soils, vegetation, and other characteristics have been collected since 1972, offer excellent opportunities to determine the effects of cattle grazing on infiltration, runoff, and erosion under rangeland conditions. When actual tests are conducted, the studies can be quickly updated to complement standard data collection procedures developed for the rainfall simulator used.

^{1/} See "Proceedings of the Rainfall Simulator Workshop", Tucson, Arizona, March 7-9, 1979.

PROGRESS REPORTS (ACHIEVEMENTS)

1. PRECIPITATION

Burgess, M. D., and C. L. Hanson. 1980. Automatic Class A pan filling system. (In review for publication in Agri. Meteor.).

Hanson, C. L. 1979. Discussion of: Interstorm relations in Pacific Northwest, by Ralph H. Frederick. J. Hydraul. Div., Amer. Soc. Civil Engin. 105(HY 11): 1459-1461.

Hanson, C. L., R. P. Morris, and D. L. Coon. 1979. A note on the dual-gage and Wyoming shield precipitation measurement systems. Water Resources Res. 15 (4): 956-960.

Hanson, C. L., R. P. Morris, R. L. Engleman, D. L. Coon, and C. W. Johnson. 1980. Spatial and seasonal precipitation distribution on Reynolds Creek Experimental Watershed in southwest Idaho. (In press: AR, Western Region Publication).

2. VEGETATION

Hanson, C. L., and R. P. Morris. 1980. Forecasting herbage production in southwest Idaho. (Being prepared for J. of Range Manage.).

Hanson, C. L., C. W. Johnson, and J. R. Wight. 1980. Loss of mountain big sagebrush (*Artemisia tridentata vaseyana*) stands in southwest Idaho during the winter of 1976-77. (In review for J. of Range Manage.).

Schumaker, G. A., C. L. Hanson, and C. W. Johnson. 1979. Loss of mountain big sagebrush (*Artemisia tridentata vaseyana*) stands in southwest Idaho during the winter of 1976-77. 32nd Annual Meeting, Society for Range Manage. February 12-15, 1979, Casper, Wyoming. p. 24-25. Abstract.

3. RUNOFF

Brakensiek, D. L. 1979. Comments on "Empirical equations for some soil hydraulic properties" by Roger B. Clapp and George M. Hornberger. Water Resources Res. 15(4): 989-990. August.

Brakensiek, D. L. 1979. Empirical and simplified models of the infiltration process. In: Infiltration Res. Planning Workshop, Part I. State of the Art Reports, USDA, St. Louis, Missouri. October 18-20, 1977. ARM-NC-4, April 1979. p. 1-9.

Brakensiek, D. L. 1979. Relating Initial Abstraction. In: Soil Infiltration. Progress Report on SCS-AR Cooperative Research on Hydrologic Modeling. Submitted to SCS.

Brakensiek, D. L., R. L. Engleman, and W. J. Rawls. 1979. Statistical properties of soil-water parameters. EOS, Trans. Amer. Geophys. Union. Vol. 60, No. 46. (Abstract) p.829-830.

Brakensiek, D. L., H. B. Osborn, and W. J. Rawls., Coordinators. 1979. Field manual for research in agricultural hydrology. USDA-SEA Agri. Handbook 224, 550 pp., Illus., February.

Brakensiek, D. L., W. J. Rawls, and W. R. Hamon. 1979. Application of an infiltrometer system for describing infiltration into soils. Trans. Amer. Soc. Agri. Engin. 22(2): 320-325, 333. April 20.

Burgess, M. D., and C. L. Hanson. 1979. Automatic soil-frost measuring system. Agri. Meteor. 20(4): 313-318.

Hanson, C. L. 1979. Simulation of arid rangeland watershed hydrology with the USDAHL-74 model. Trans. Amer. Soc. Agri. Engin. 22(2): 304-309.

Hanson, C. L., E. L. Neff, J. T. Doyle, and T. L. Gilbert. 1980. Runoff curve numbers for Northern Great Plains rangelands. (Being prepared for J. of Soil and Water Conserv.).

Hanson, C. L., E. L. Neff, and A. D. Nicks. 1980. Estimating SCS runoff curve numbers on native grazing lands. In: Vol. III, Supporting documentation, CREAMS. A Field Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems. Chapter 3, p. 27-34. (In press; USDA Publication).

Johnson, C. W., G. M. Secrist, G. C. Scholton, and J. R. Baum. 1980. Watershed management in action on the Boise Front. (Approved for presentation at the 1980 Watershed Management Symposium and in review for publication in the Proc. Amer. Soc. Civil Engin., July 21-23, Boise, Idaho).

Rawls, W. J., D. L. Brakensiek, and H. B. Osborn. 1979. Field Manual for Research in Agricultural Hydrology. Pres. Amer. Soc. Agri. Engin. Winter Meeting, New Orleans, December.

Rawls, W. J., D. L. Brakensiek, and H. B. Osborn. 1979. Research procedures in agricultural hydrology. Proc. of 18th IAHR Congress, Rome.

Smith, J. P., and C. W. Johnson. 1979. Streamflow characteristics of Reynolds Creek watersheds. (Paper No. PNW 79-208, Pres. at the 34th Annual Meeting of the Pacific Northwest Region, Amer. Soc. Agri. Engin., October 3-5, Boise, Idaho).

Soil infiltration progress reported at the following meetings:

SCS National Hydrology Conference, DeGray State Park, Arkansas, September 1979.

SCS-AR Workshop on Hydrologic Classification of Soils, Lincoln, Nebraska, January 1980.

1979 AGU Fall Meeting, San Francisco, December 1979.

BLM-Great Basin Watershed Workshop, Elko, Nevada, November 1979.

BLM-Idaho Water Resources Workshop, Boise, Idaho, November 1979.

BLM-SEA Reynolds Creek Research Review, May 22-23, 1979.

Shoshone District (BLM) Reynolds Creek Research Review, July 1979.

4. EROSION AND SEDIMENT

Johnson, C. W., and K. A. Gebhardt. 1979. Sagebrush rangeland soil loss and sediment yield. (Paper No. PNW 79-206, presented at the 34th Annual Meeting of the Pacific Northwest Region, Amer. Soc. Agri. Engin., October 3-5, Boise, Idaho, and in review for publication).

Johnson, C. W., G. A. Schumaker, and J. P. Smith. 1980. Effects of grazing and sagebrush control on potential erosion. (Approved for publication in the J. of Range Manage., July or September issue).

Johnson, C. W., and J. P. Smith. 1979. Reducing stream sediment loads by irrigation diversions. Trans. Amer. Soc. Agri. Engin. 22(3): 573-576.

5. WATER QUALITY

Stephenson, G. R. 1979. Effect of drought on groundwater supplies in a rangeland watershed in southwest Idaho. Pres. at 60th Annual Meeting, Amer. Geophys. Union, Washington D.C. May. (Abstract).

Stephenson, G. R. 1979. Effects of grazing on water quality of rangeland streams. Pres. at Great Basin Watershed Workshop, BLM, Elko, Nevada, November.

Stephenson, G. R. 1979. Importance of study design in water quality investigations. Pres. at Idaho Water Resources Workshop, BLM, Boise, Idaho. November.

Stephenson, G. R., and J. E. Dixon. 1979. Water quality characteristics of runoff from winter cattle feeding pastures. Pres. at 34th Annual Meeting, Pacific Northwest Region, Amer. Soc. Agri. Engin., Boise, Idaho, October.

Stephenson, G. R., J. E. Dixon, A. J. Lingg, D. V. Naylor, and D. D. Hinman. 1979. Evaluation of rangeland management practices for water quality. Paper No. 79-2505, Pres. at Winter Meeting, Amer. Soc. Agri. Engin., New Orleans, Louisiana, December).

Stephenson, G. R., and R. C. Rychert. 1979. Bottom sediment: a source of E. coli in rangeland streams. (Submitted to J. of Range Manage.).

Stephenson, G. R., and J. F. Zuzel. 1979. Groundwater recharge characteristics in a semiarid environment. (Prepared for publication in J. of Hydrol.).

6. RAINFALL SIMULATION

Johnson, C. W. 1979. Rainfall simulation and watershed research. In Proc. of the Rainfall Simulator Workshop, USDA, ARM-W-10, March 7-9, Tucson, Arizona.

